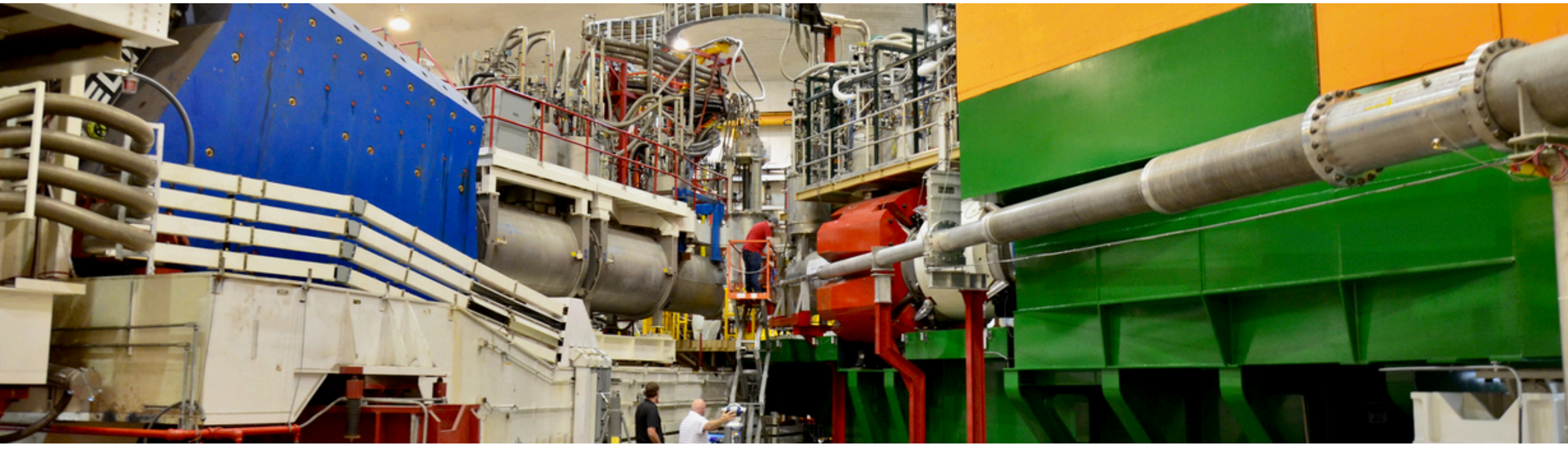


Deuteron Electro-Disintegration Experiment (E12-10-003)

Carlos Yero

Spokespeople: Drs. Werner Boeglin and Mark Jones

January 28, 2019

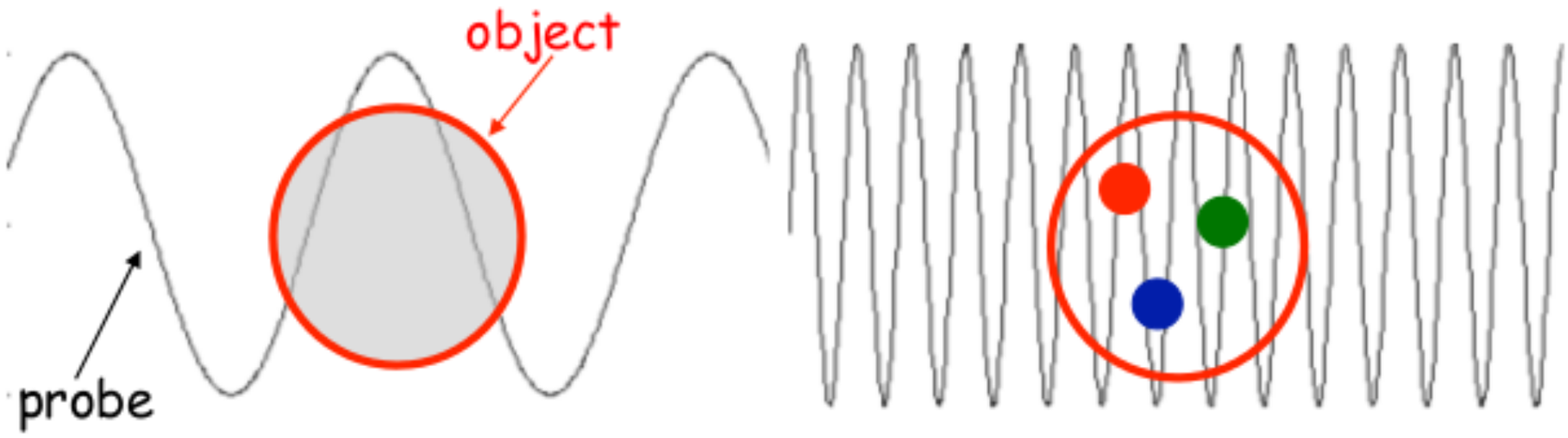
Motivation

- ☑ Study Deuteron at short ranges (< 1fm).

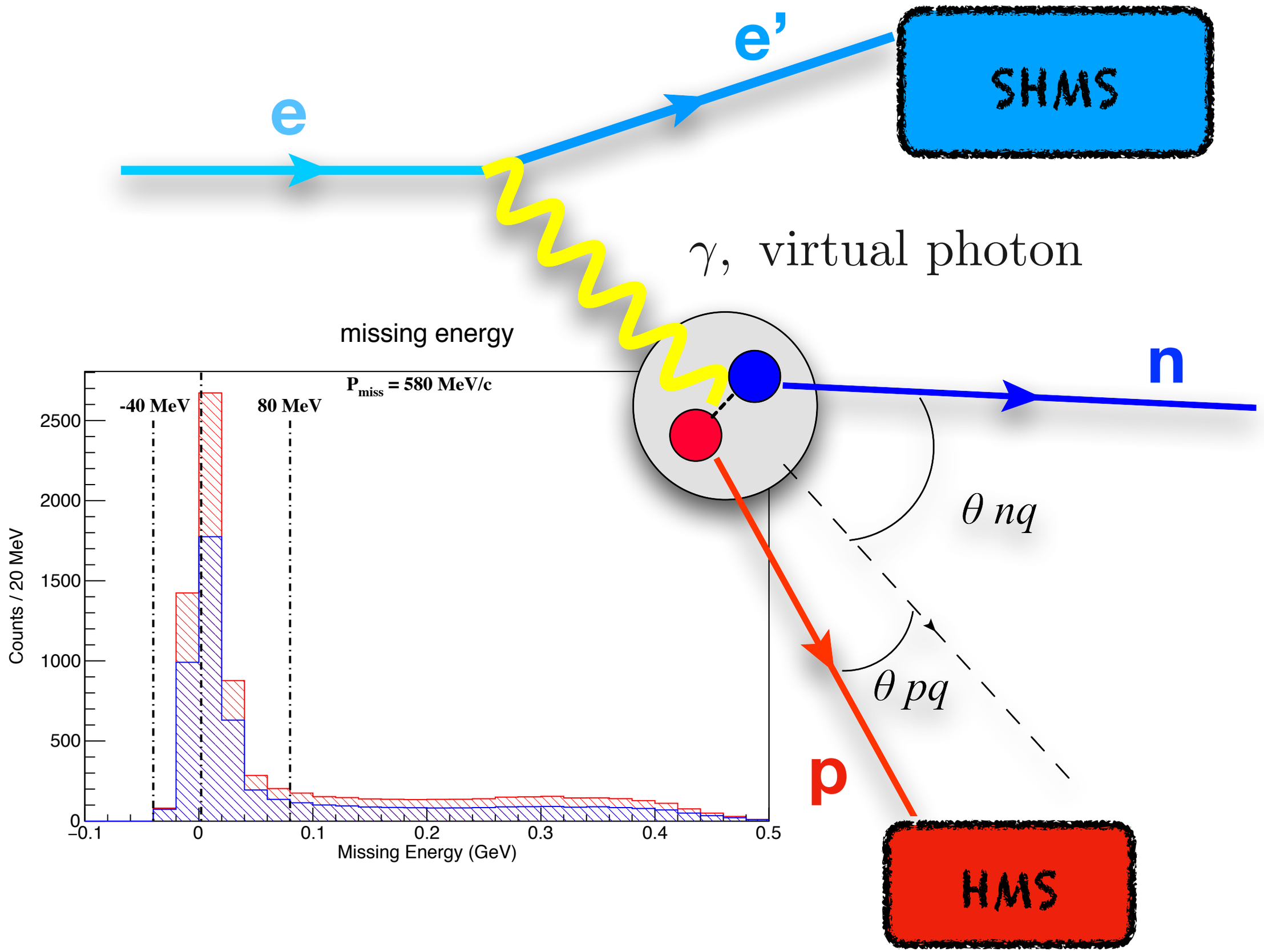
  High momentum transfers probe the Deuteron at smaller distances.
  Smaller inter-nucleon distances enables one to access the high momentum components of nucleons

- ☑ Extract D(e,e'p)n cross-section beyond 500 MeV/c missing momentum at high Q2

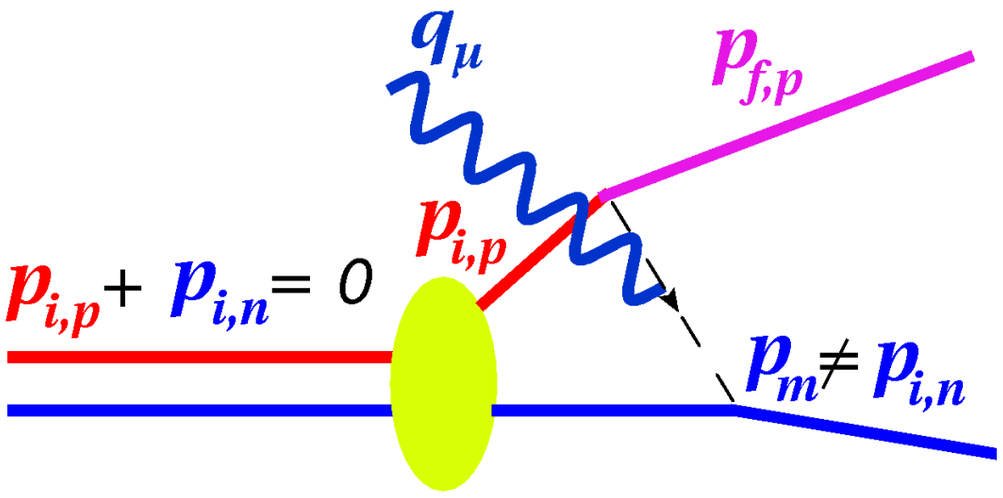
- ☑ Extract momentum distributions (not an observable) from cross sections.



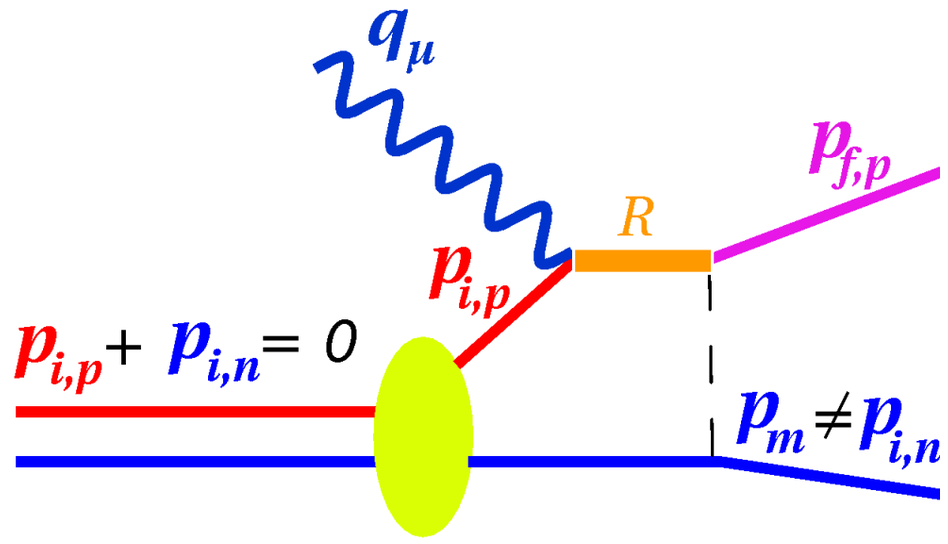
D(e,e'p)n Reaction Kinematics



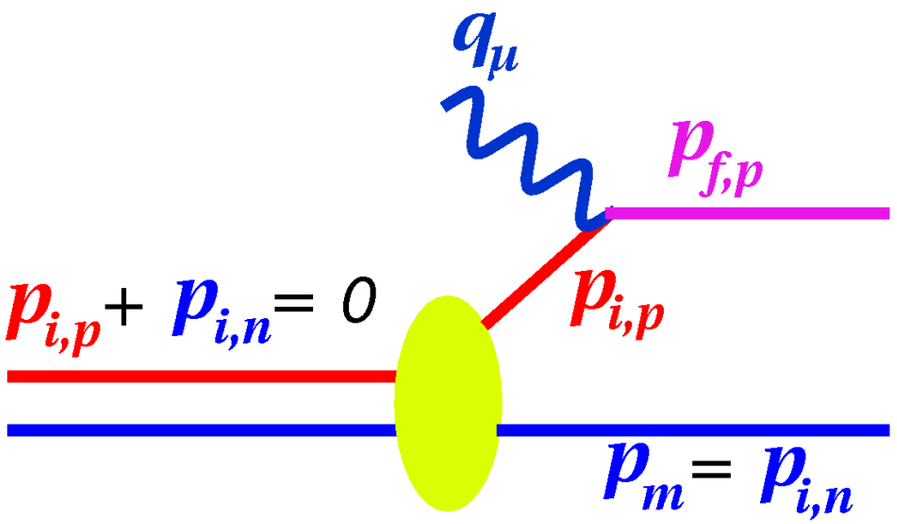
D(e,e'p)n Interactions



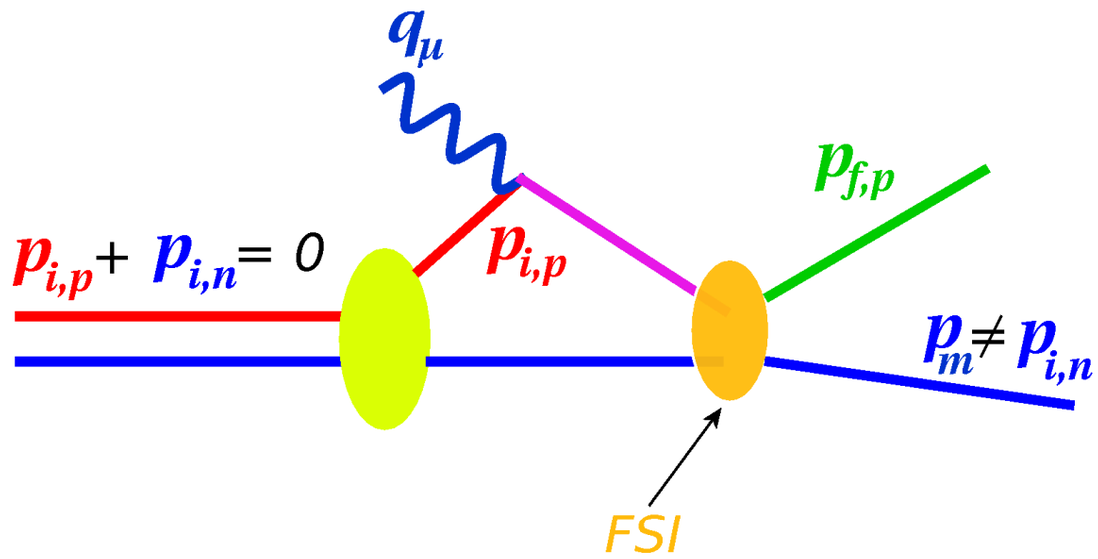
Meson-Exchange Currents (MEC)



Isobar Configurations (IC)



Plane Wave Impulse Approximation (PWIA)



Final State Interactions (FSI)

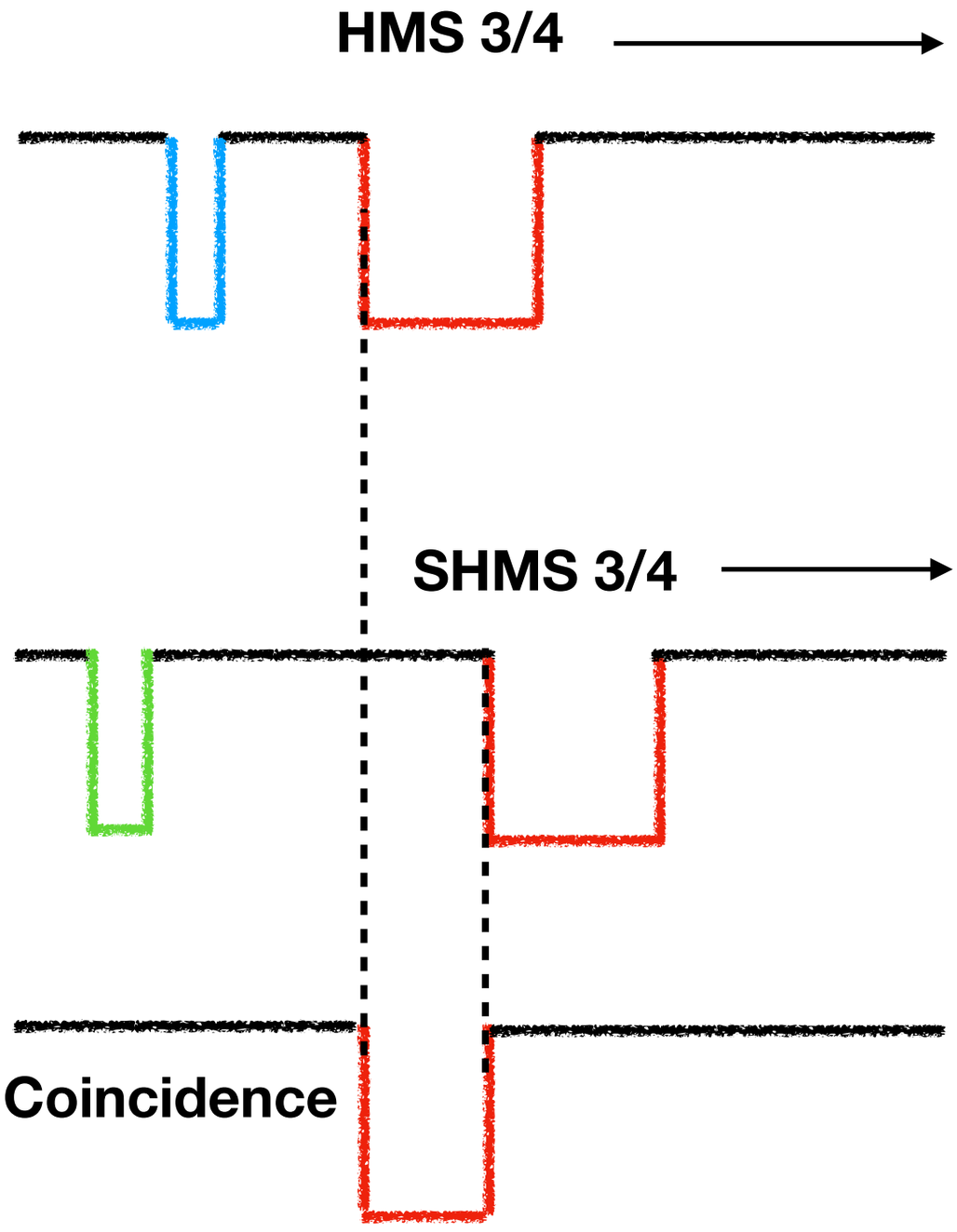
E12-10-003

Initial Analysis Procedure

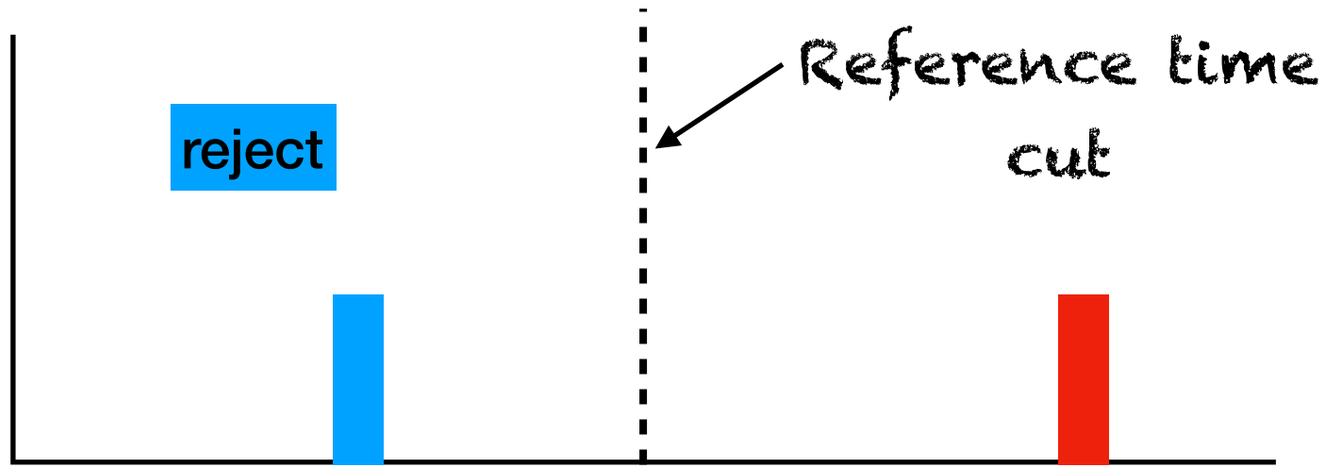
- Reference Time Cuts
- TDC/ADC Time Window Cuts
- Detector Calibration

Reference Time Cuts: Basic Principle

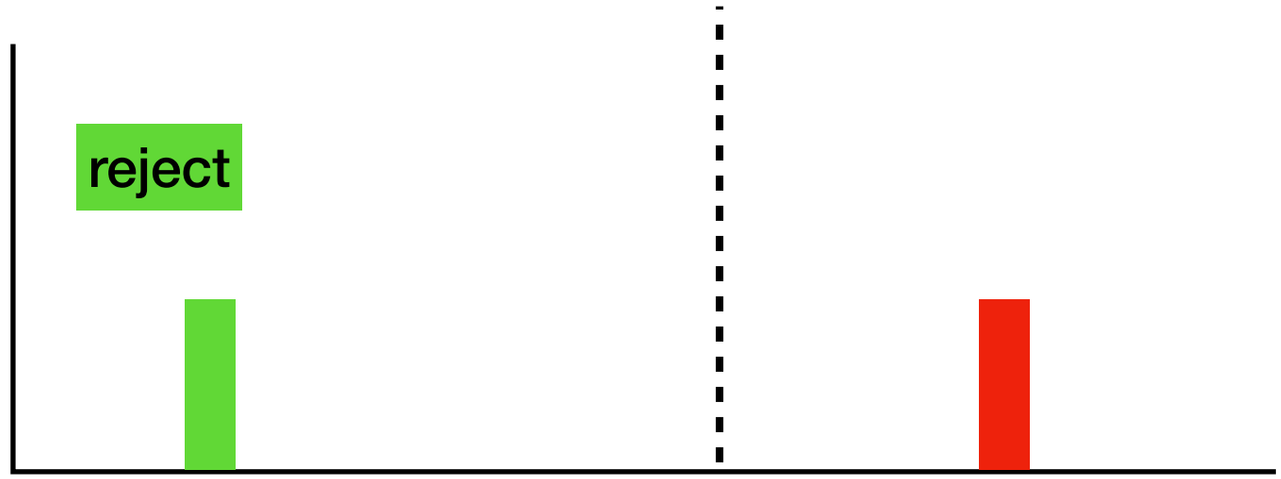
☑ **Ref. Time subtraction on Detector signals improves timing resolution**



HMS TDC Reference Time Spectrum

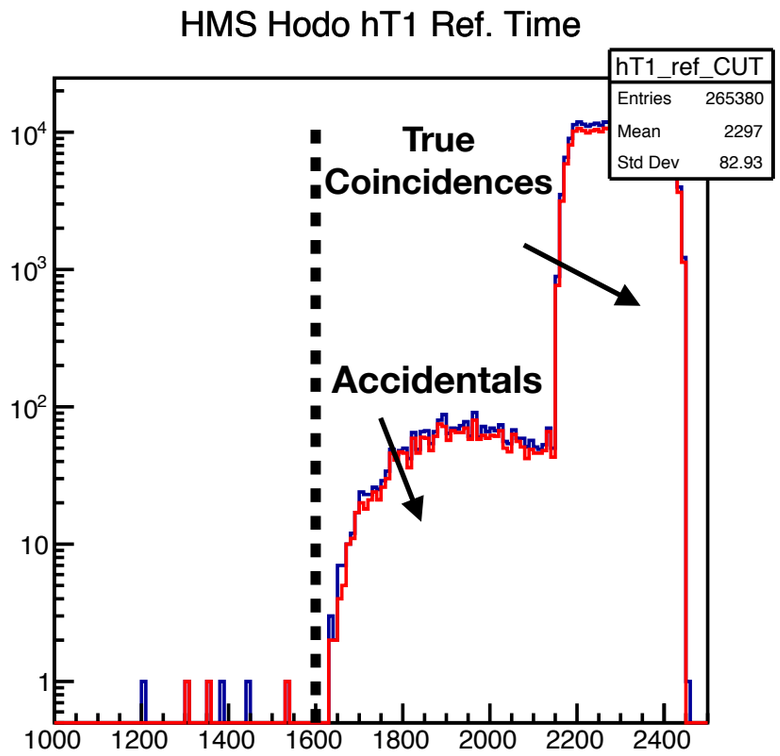


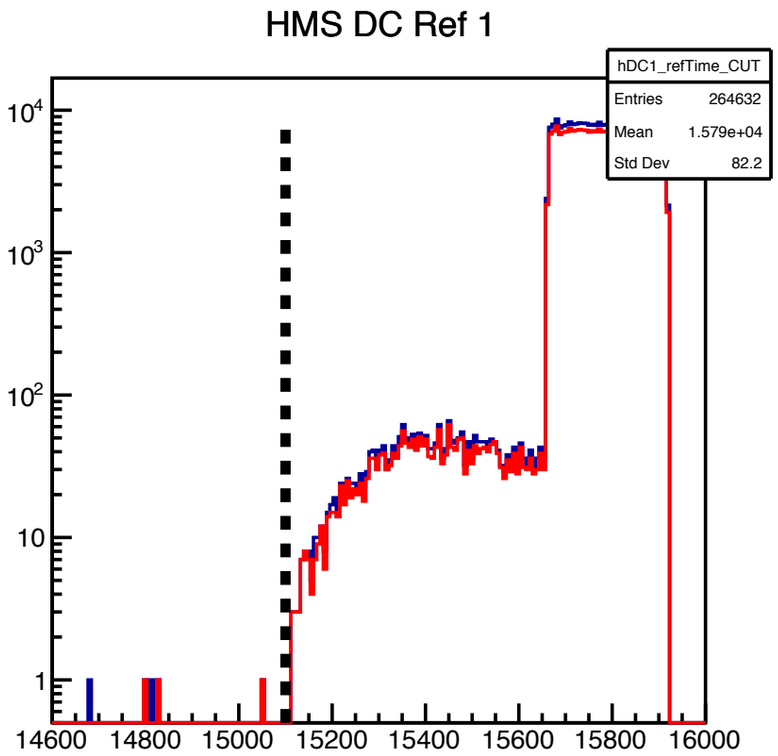
SHMS TDC Reference Time Spectrum

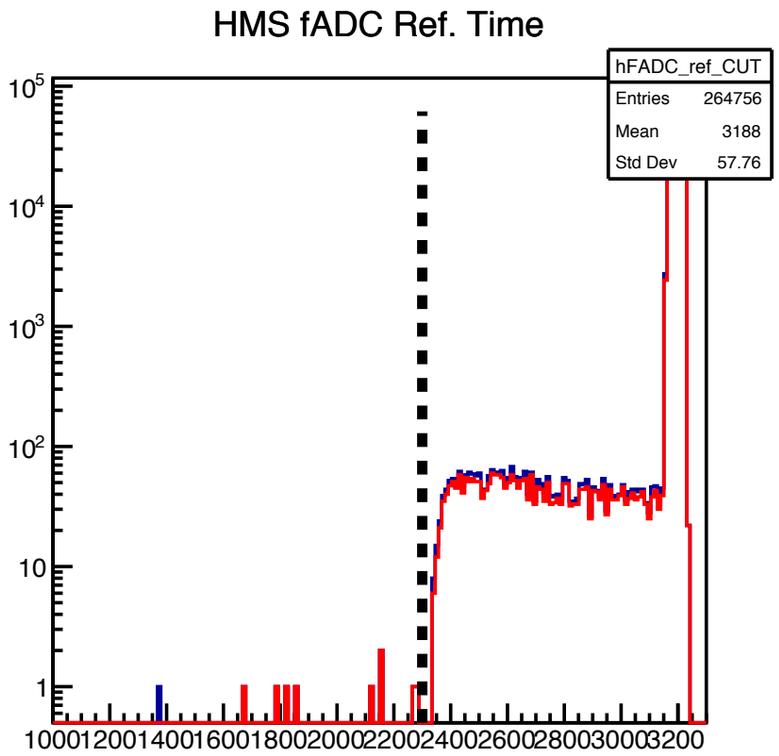


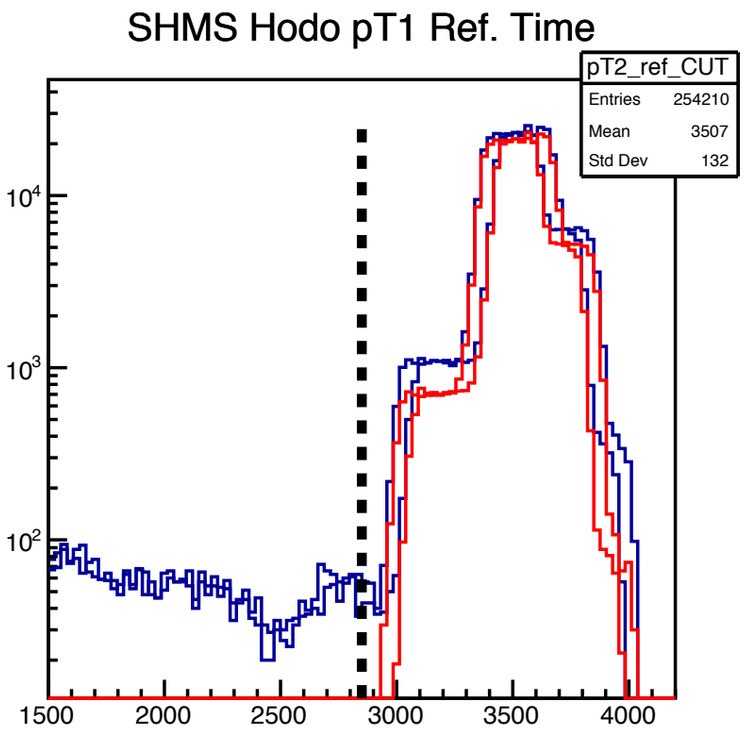
hcana **(Hall C Analyzer) selects the 1st hit beyond the cut as ref. time !**

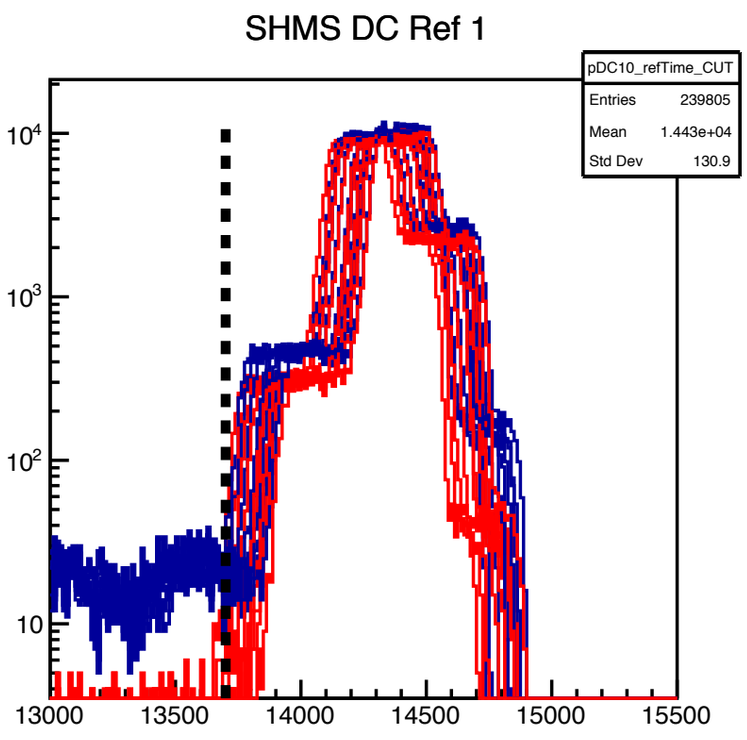
Reference Time Cuts

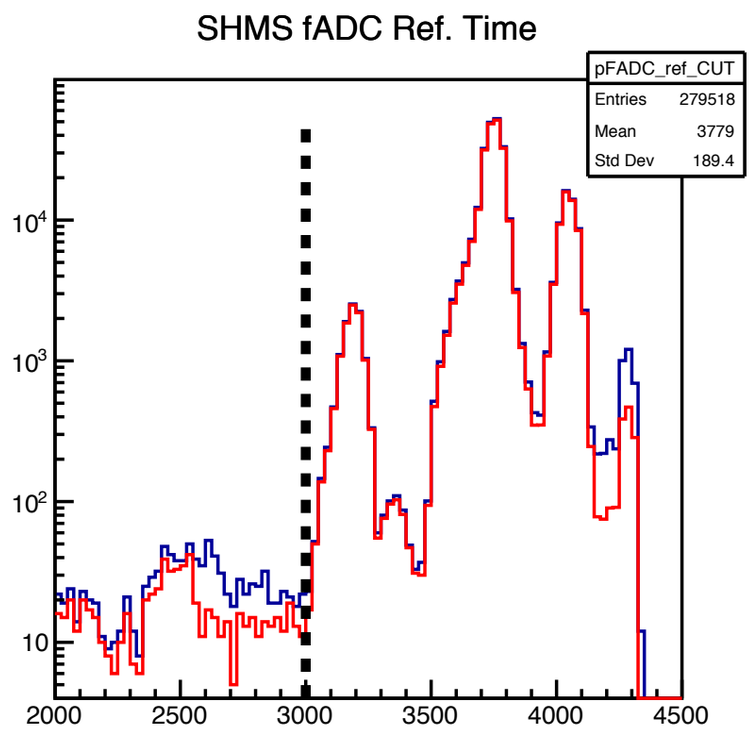




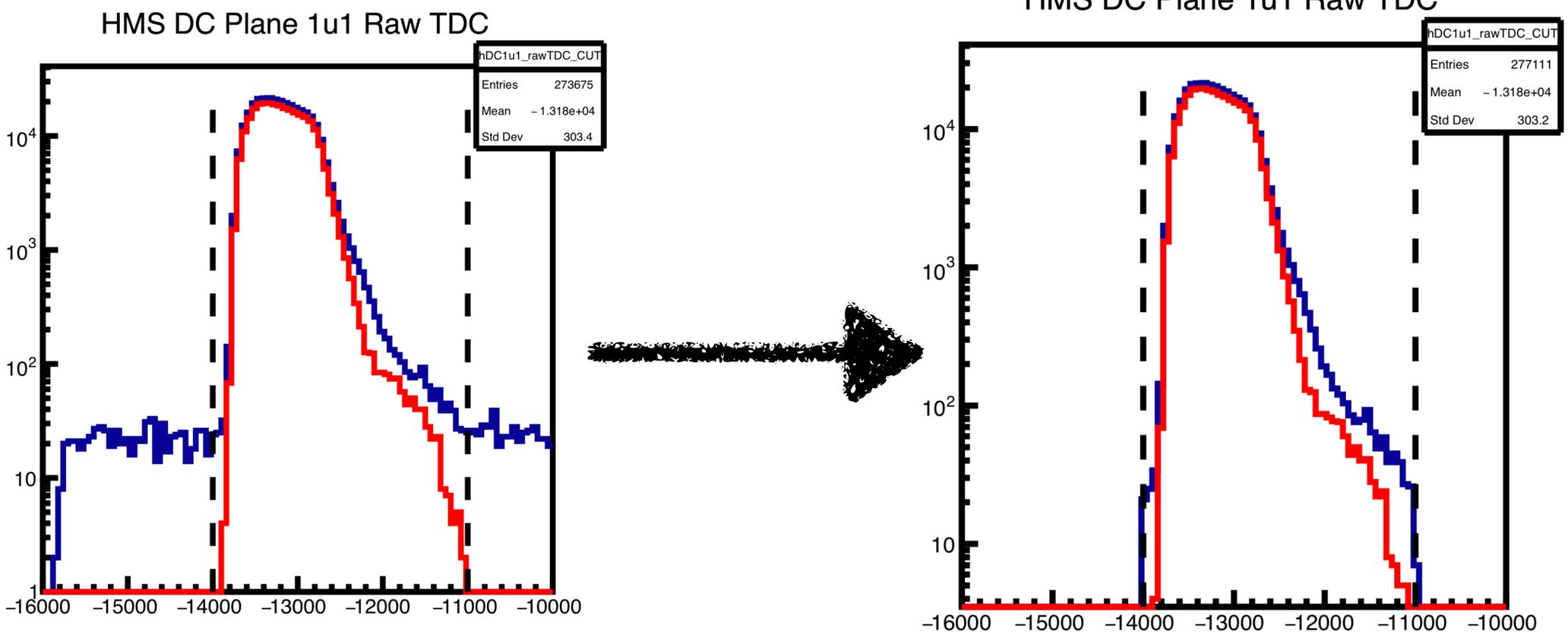


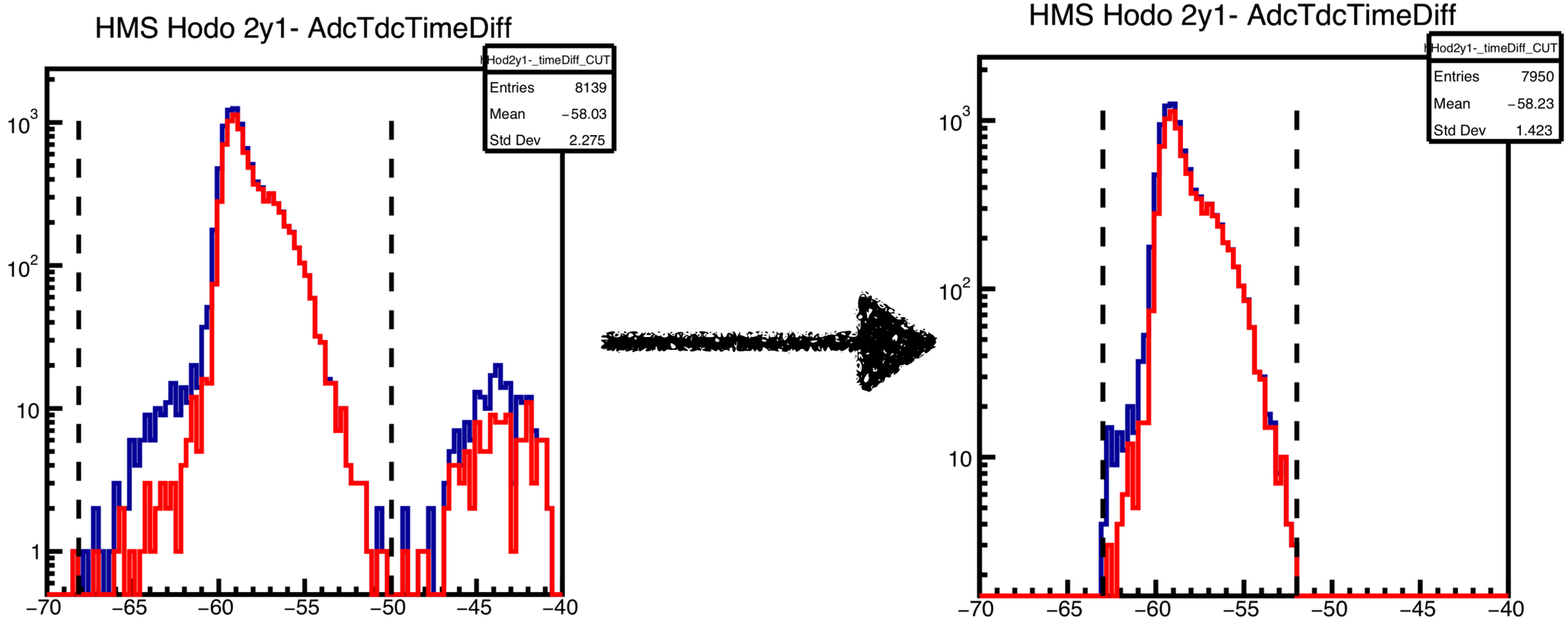




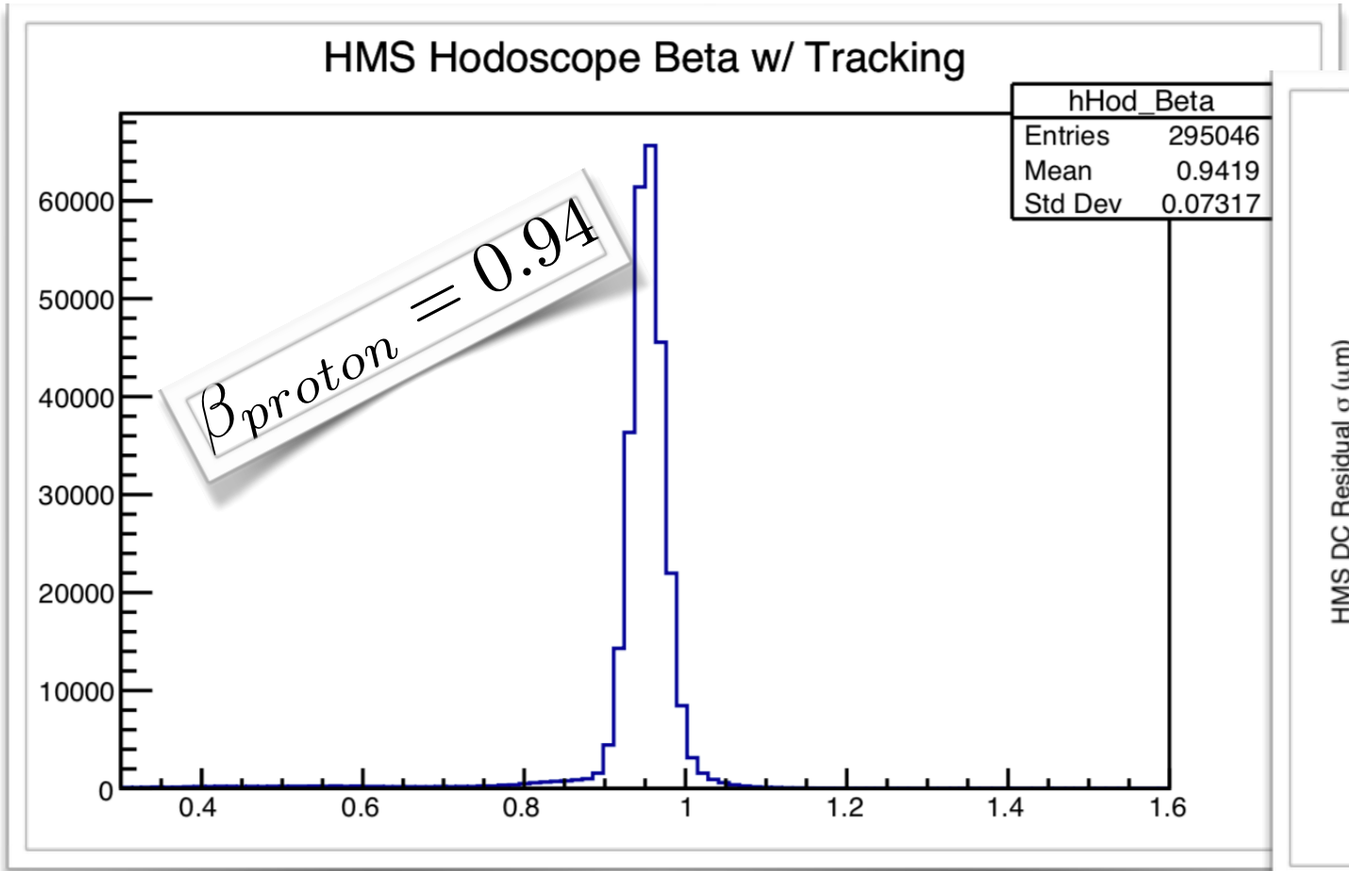


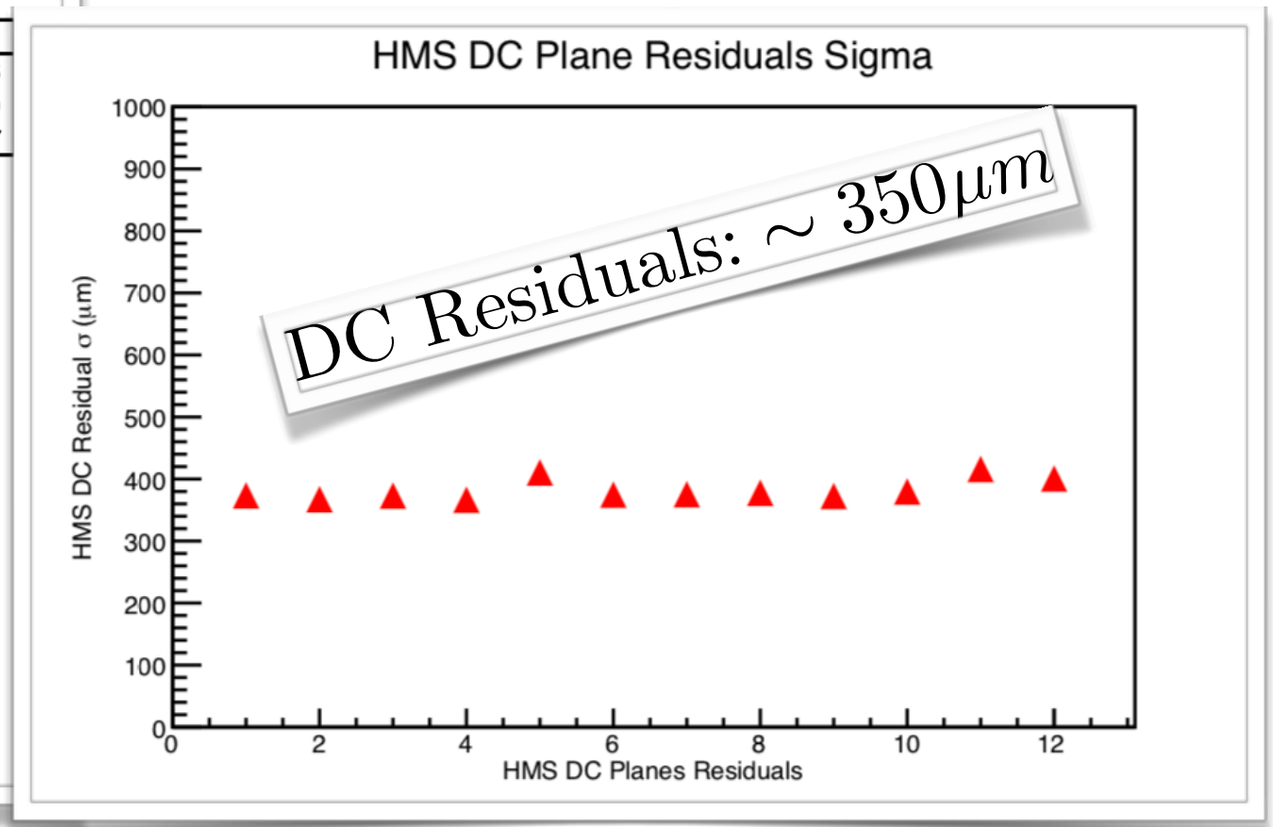
Time Window Cuts

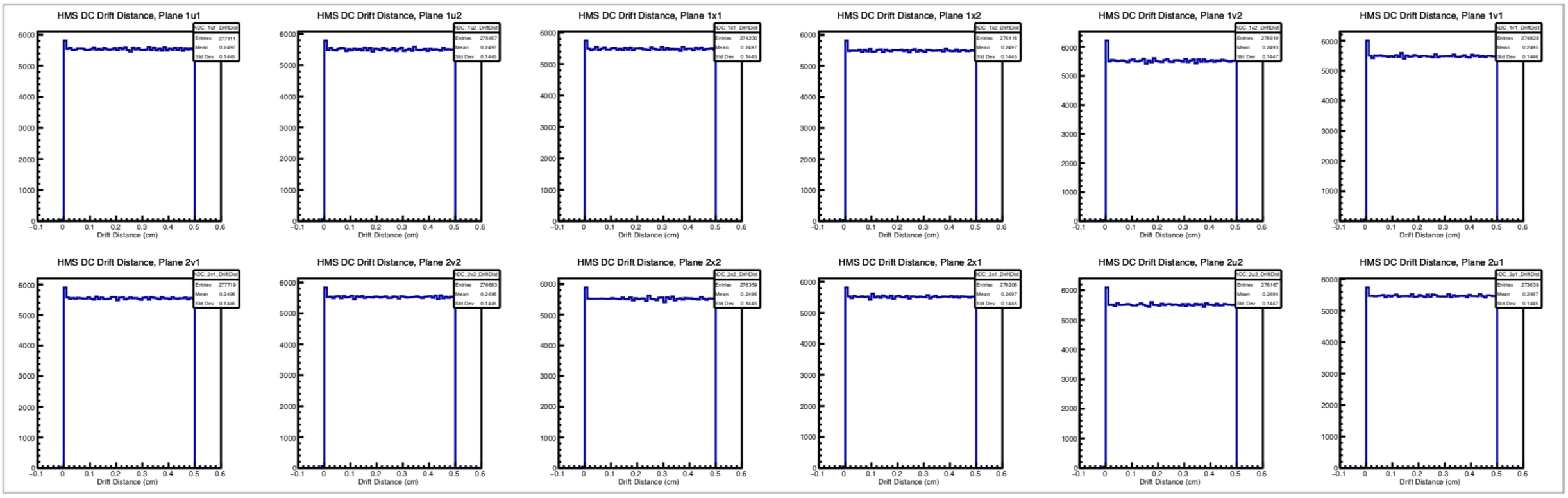




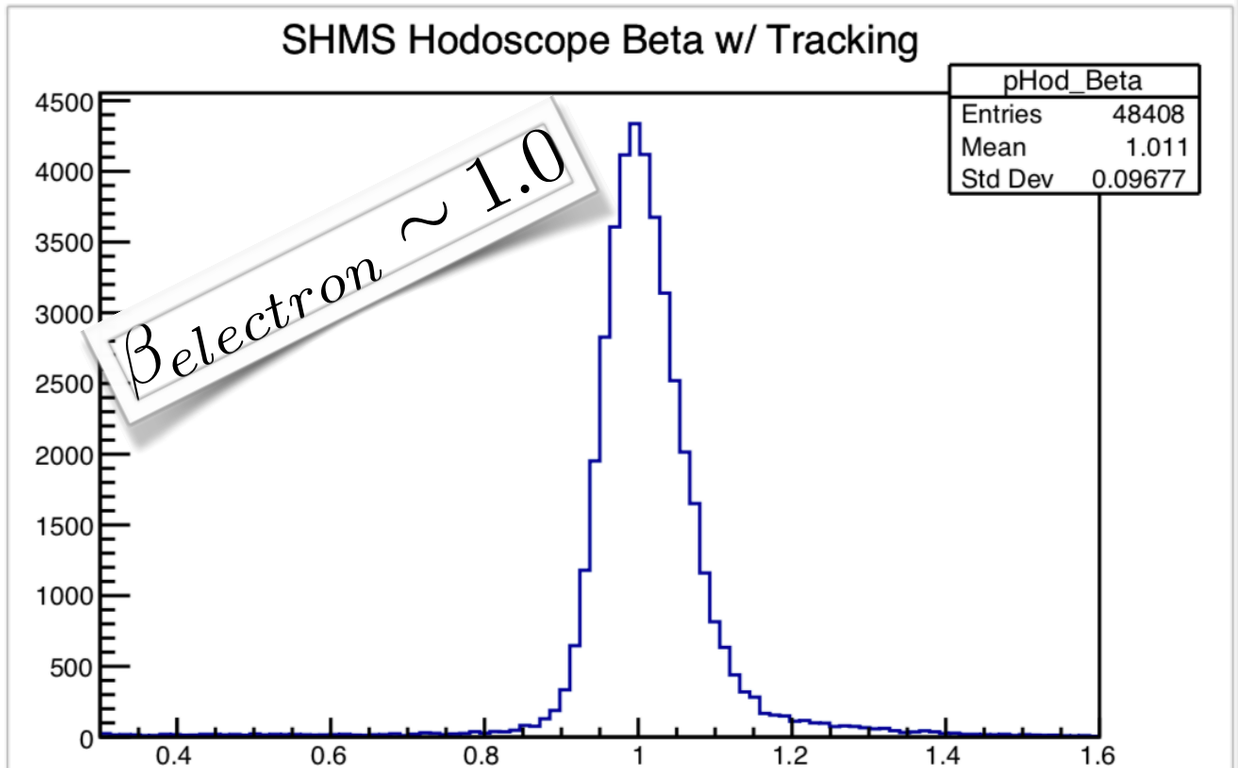
HMS Detector Calibration

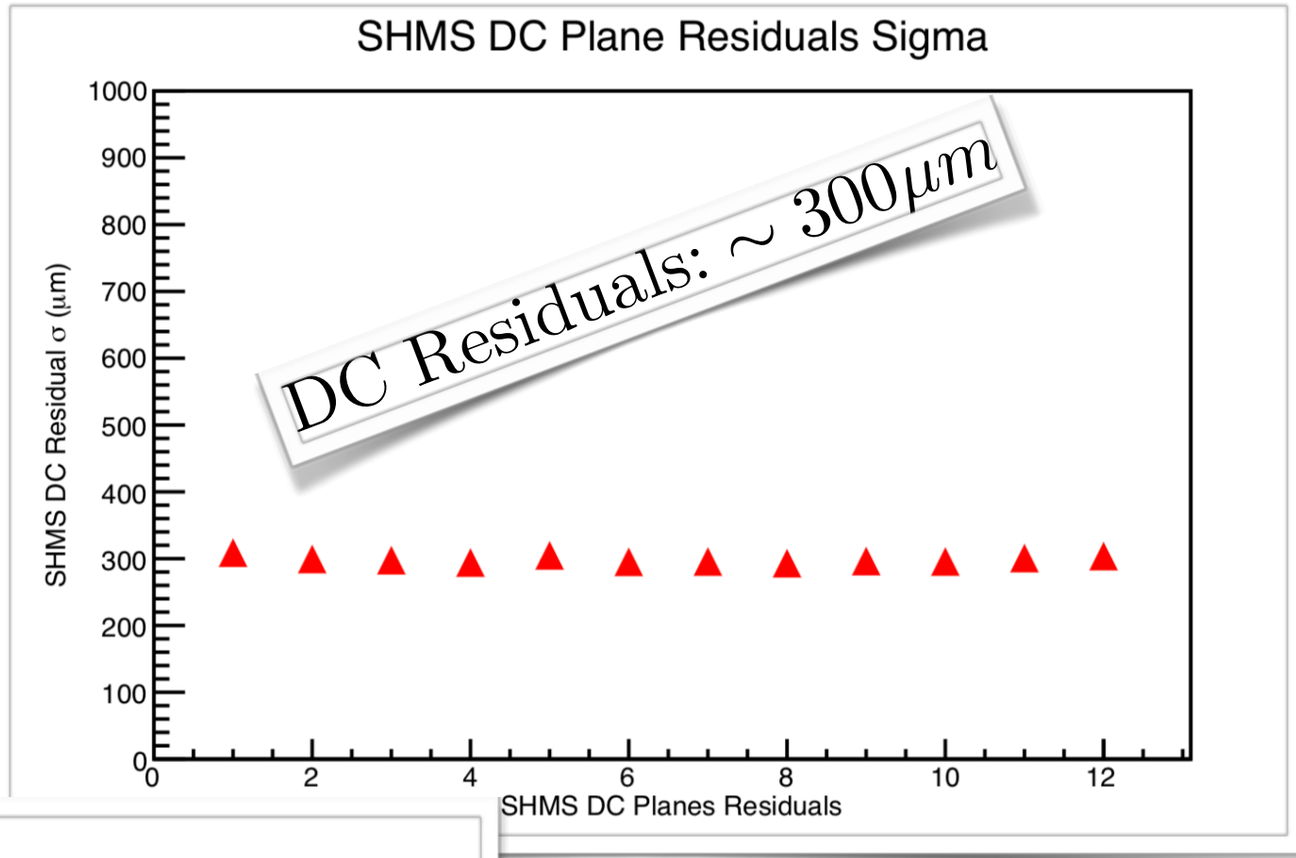


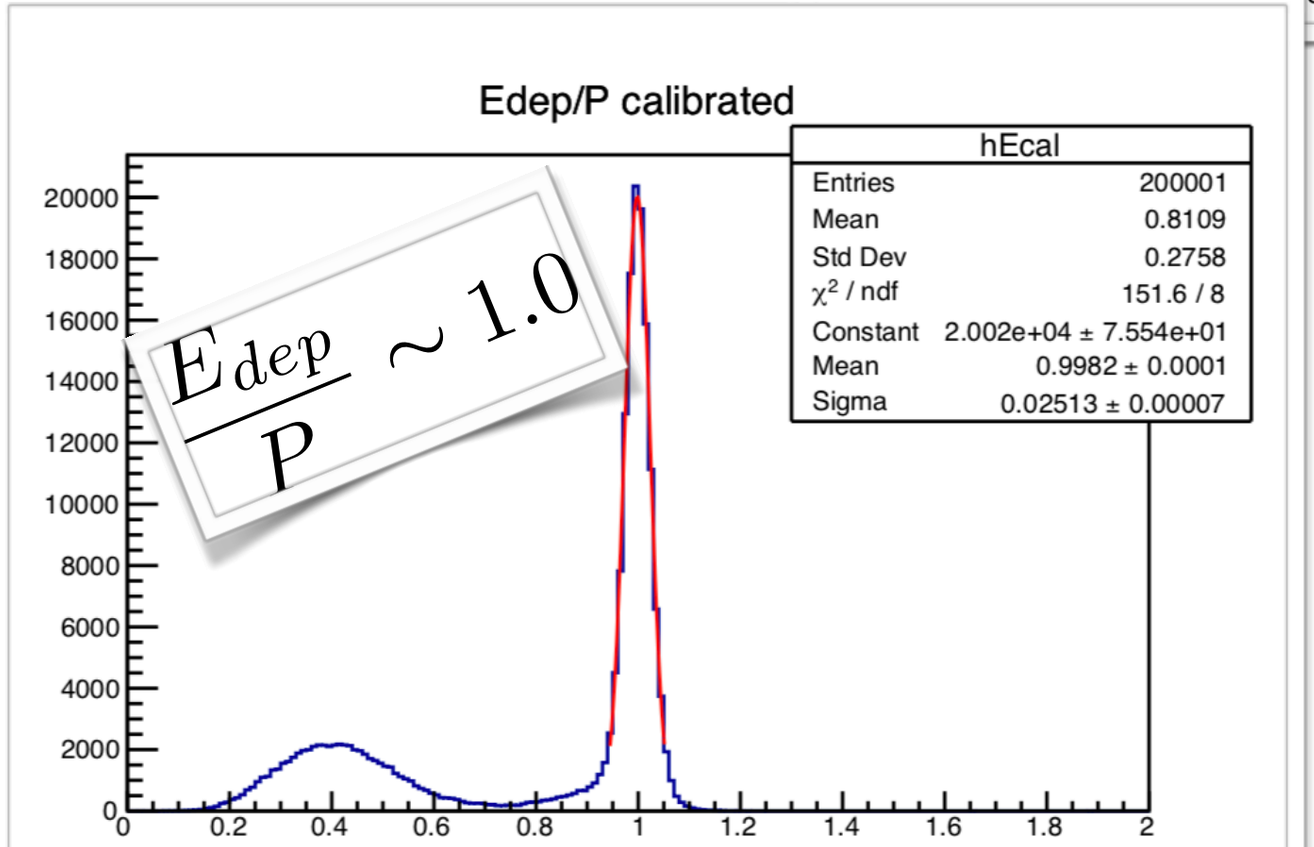




SHMS Detector Calibration







E12-10-003

H(e,e'p) Analysis:

HMS/SHMS Momentum Corrections and Optimization

Why Optimize H(e,e'p) before Studying the D(e,e'p)n Reaction ?

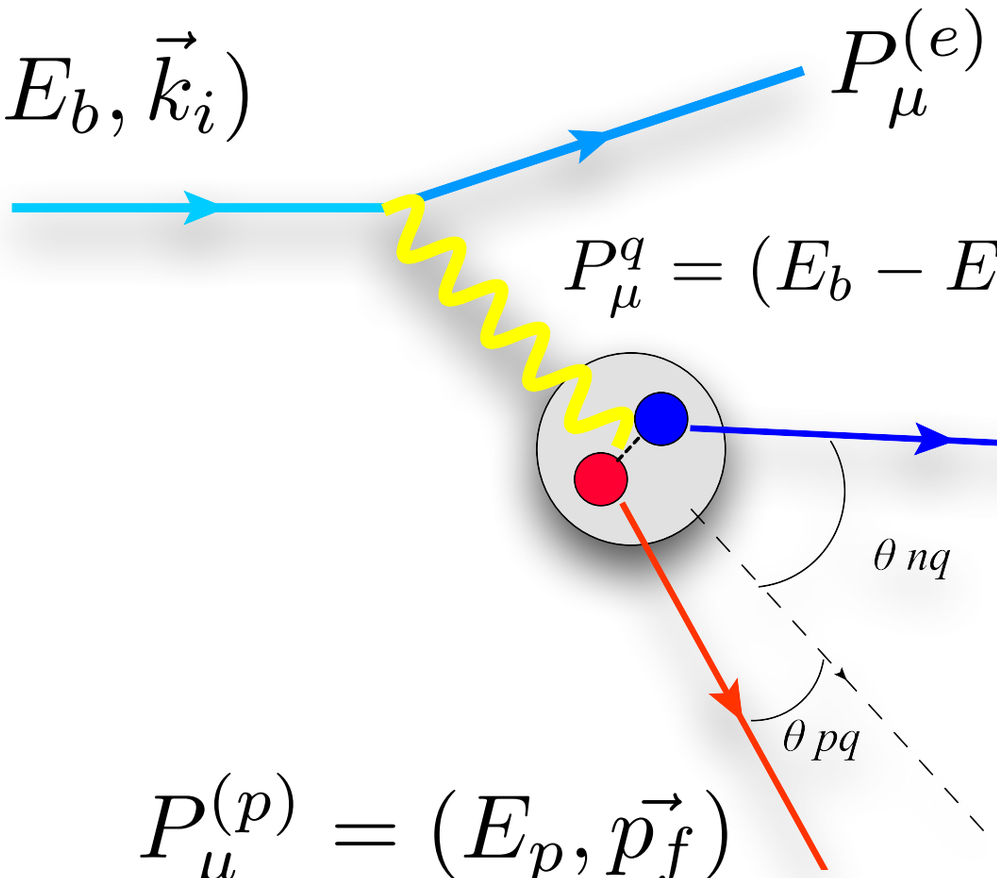
$$P_\mu^{(e)} = (E_b, \vec{k}_i)$$

$$P_\mu^{(e)} = (E_e, \vec{k}_f)$$

$$P_\mu^{q} = (E_b - E_e, \vec{k}_i - \vec{k}_f)$$

$$P_\mu^{(n)} = (E_n, \vec{p}_{miss})$$

$$P_\mu^{(p)} = (E_p, \vec{p}_f)$$



$$\vec{q} \equiv \vec{k}_i - \vec{k}_f = \vec{p}_f + \vec{p}_{miss}$$

$$q = p_f \cos(\theta_{pq}) + p_{miss} \cos(\theta_{nq})$$

$$\boxed{p_{miss} = \frac{|\vec{k}_i - \vec{k}_f| - p_f \cos(\theta_{pq})}{\cos(\theta_{nq})}}$$

"At D(e,e'p)n 80 MeV setting, any variation in the electron or proton momentum will have a large impact on the missing momentum as the electron or proton momentum are > 1 GeV/c "

E12-10-003: Original Kinematics

Target	SHMS angle	SHMS momentum	HMS angle	HMS momentum
LH2	12.2 deg	-8.70 GeV/c	37.3 deg	+2.938 GeV/c

Target	SHMS angle	SHMS momentum	HMS angle	HMS momentum
Al	12.2 deg	-8.70 GeV/c	37.3 deg	+2.938 GeV/c

Target	SHMS angle	SHMS momentum	HMS angle	HMS momentum	Missing Momentum
LD2	12.2 deg	-8.70 GeV/c	38.896 deg	+2.844 GeV/c	80 MeV

Target	SHMS angle	SHMS momentum	HMS angle	HMS momentum	Missing Momentum
LD2	12.2 deg	-8.70 GeV/c	55.0 deg	+2.194 GeV/c	580 MeV
LD2	12.2 deg	-8.70 GeV/c	58.4 deg	+2.091 GeV/c	750 MeV

Minimum Charge Requirements MET:

	Pm = 580 MeV/c	Pm = 750 MeV/c
Min Charge:	2880 mC	6048 mC
Obtained:	5049 mC	7865 mC

H(e,e'p) Elastics Kinematics Used In Optimization Procedure

RUN	SHMS Momentum [GeV]	SHMS Angle [deg]	HMS Momentum [GeV]	HMS Angle [deg]	SHMS Delta Range [%]	HMS Delta Range [%]
3288	-8.7	12.194	2.938	37.338	(-6, 2)	(-12,10)
3371	-8.7	13.93	3.480	33.545	(-12, 4)	(-12,10)
3374	-8.7	9.928	2.31	42.9	(3, 8)	(-12,10)
3377	-8.7	8.495	1.8899	47.605	(8, 12)	(-12,10)

HMS Checks:

- ☑ **Is there any correlation between delta and focal plane quantities?**
- ☑ **HMS Momentum is below Dipole Saturation (< ~ 4.2 GeV)**
- ☑ **Assume Beam Energy and HMS Angle are well known.**
- ☑ **Formula is ONLY valid for H(e, e'p) kinematics**

$$P_{calc}(E_b, \theta_p) = \frac{2M_p E_b (E_b + M_p)\cos(\theta_p)}{M_p^2 + 2M_p E_b + E_b^2 \sin^2(\theta_p)}$$

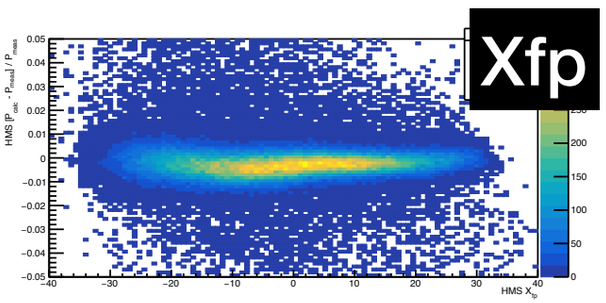
$$\boxed{P_{fr}(E_b, \theta_p, P_{meas}) \equiv \frac{P_{calc}(E_b, \theta_p) - P_{meas}}{P_{meas}}}$$ ***"Fractional Momentum"***

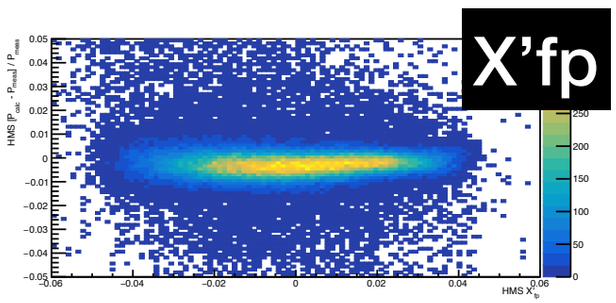
HMS Fractional Momentum vs. Focal Plane

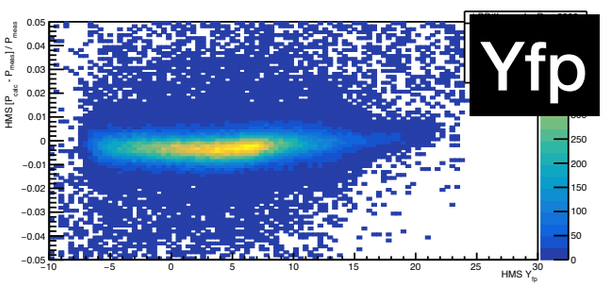
☑ **Is there any correlation between delta and focal plane quantities?**

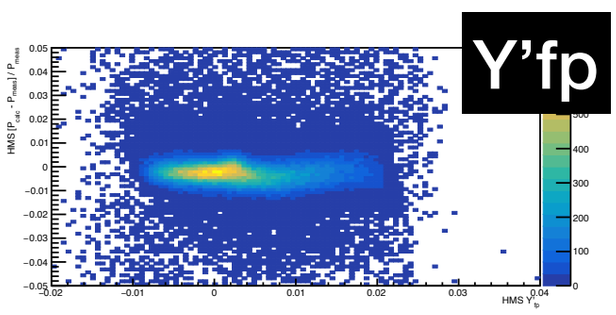
NO CORRELATIONS OBSERVED !

Run: 3288

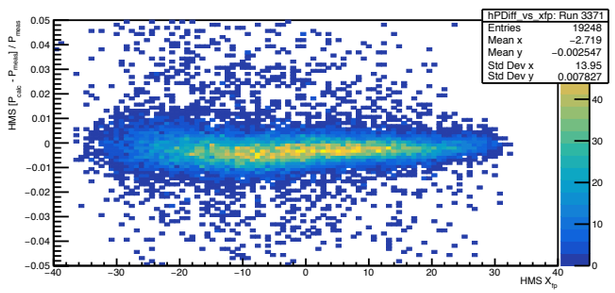


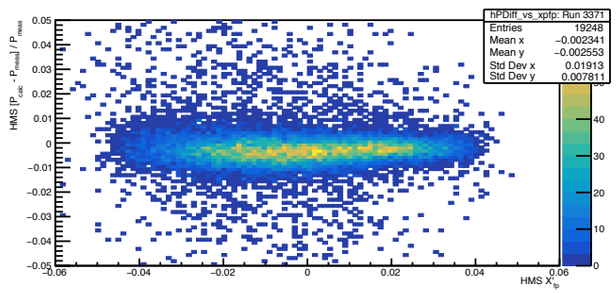


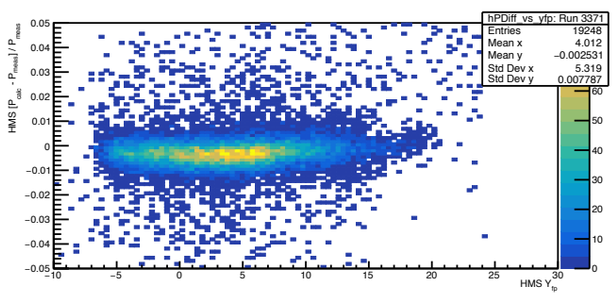


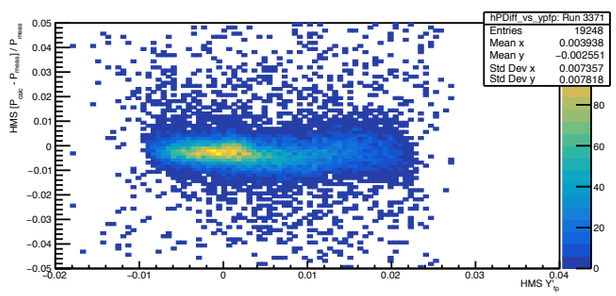


Run: 3371

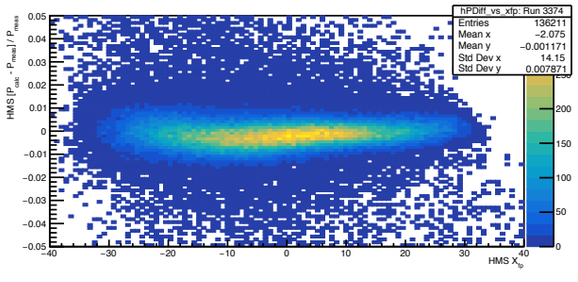


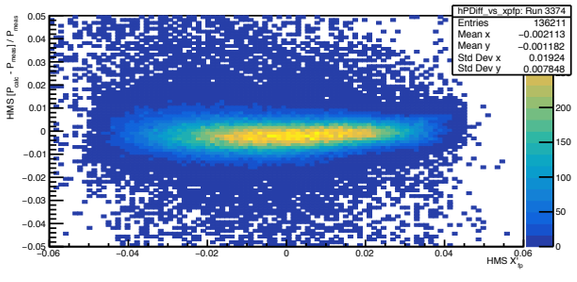


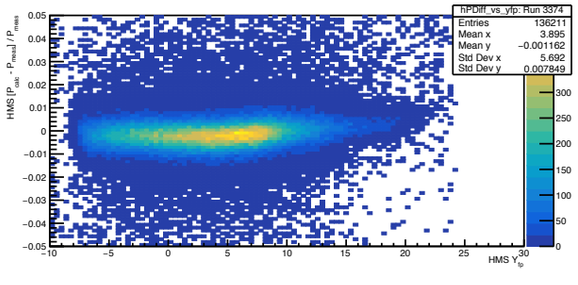


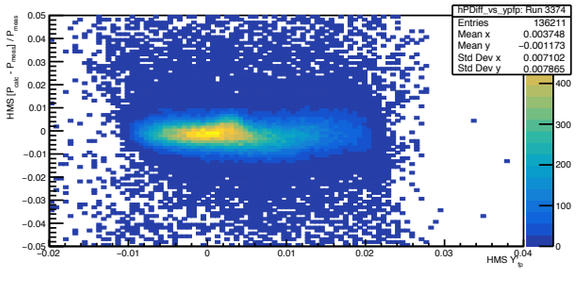


Run: 3374









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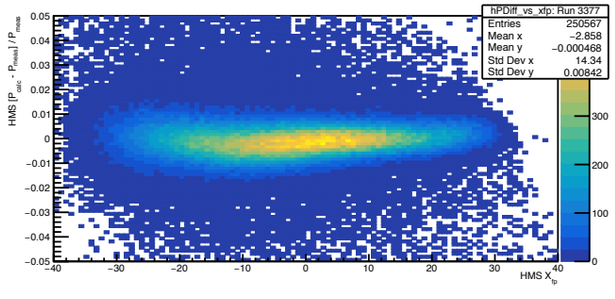
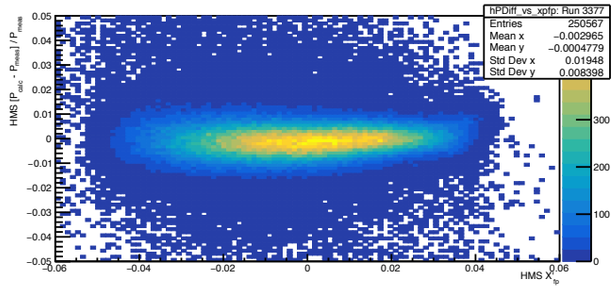
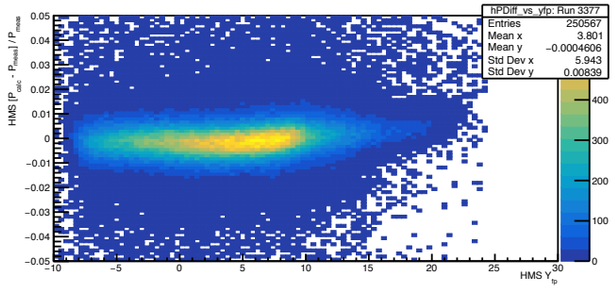
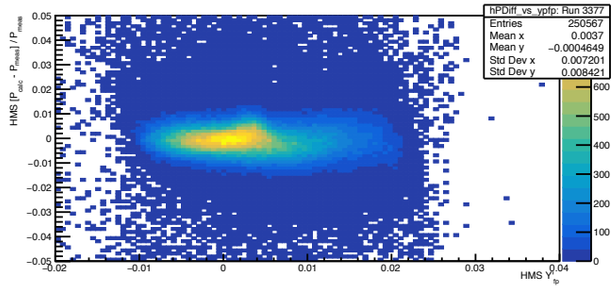
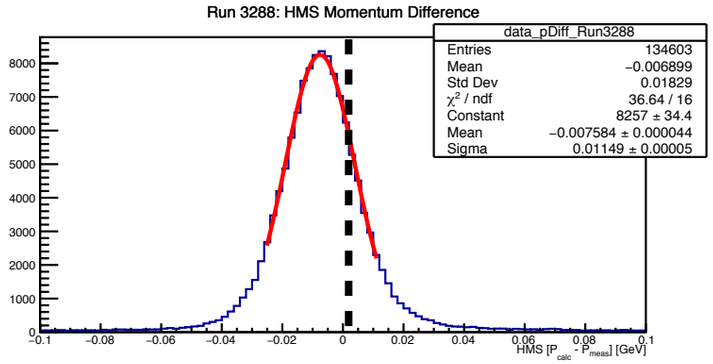


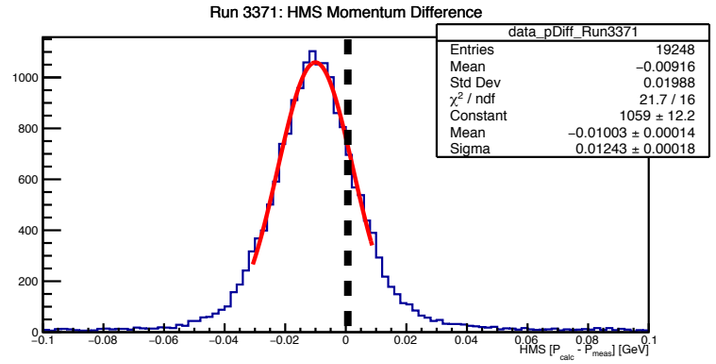


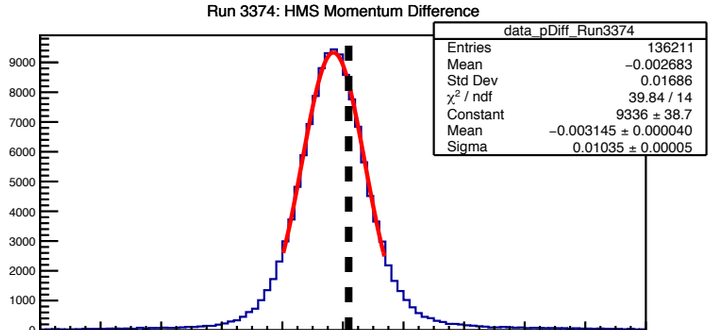


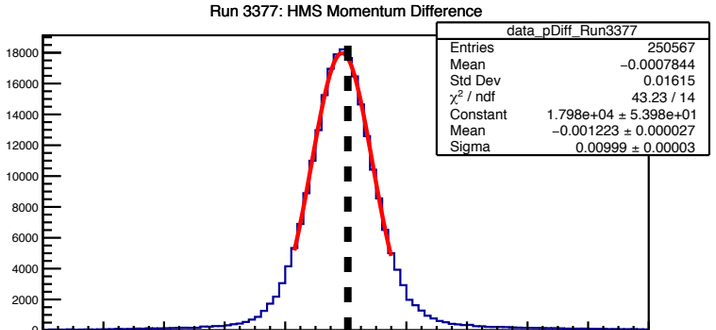


HMS Fractional Momentum DATA/SIMC



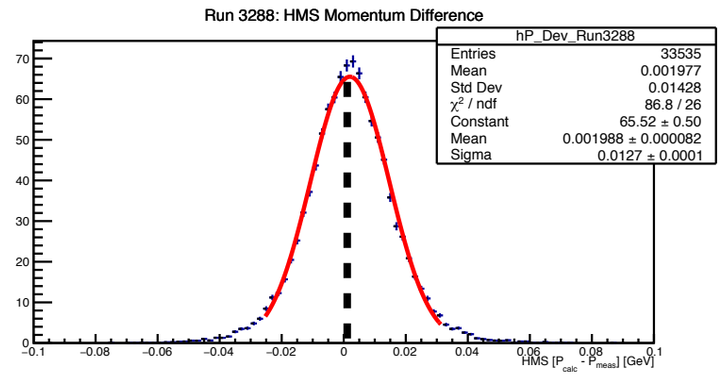


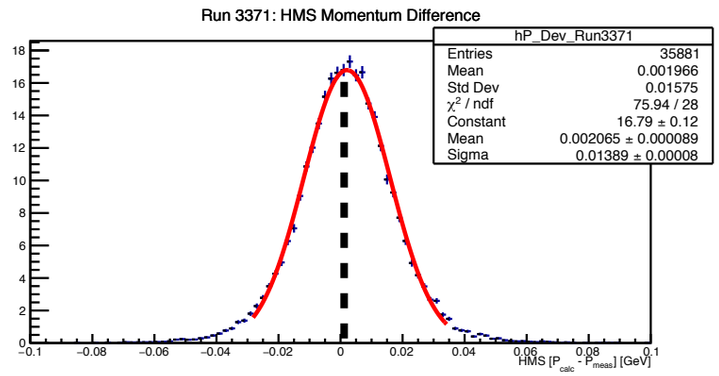


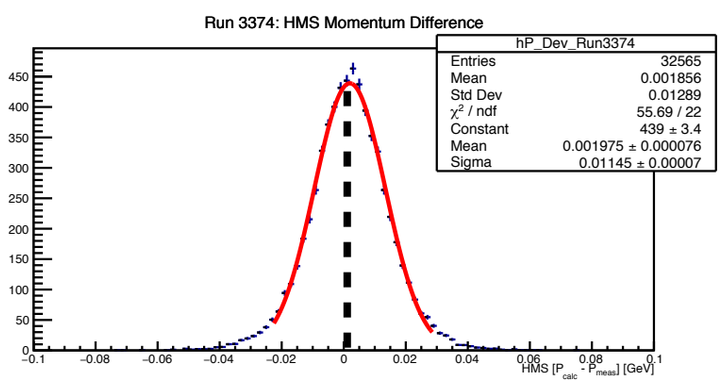


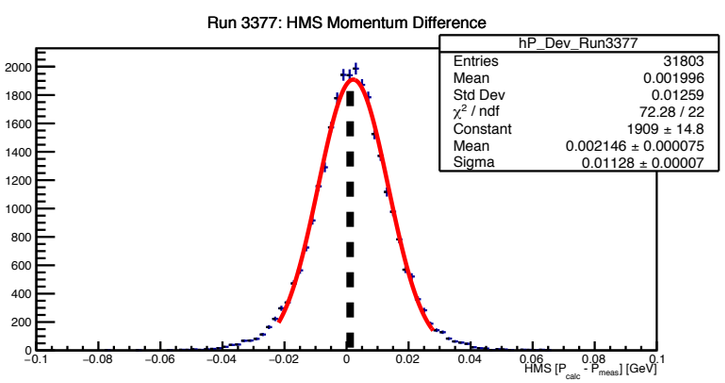
DATA:
fractional momentum is OFFSET!

SIMC:
fractional momentum is OK!

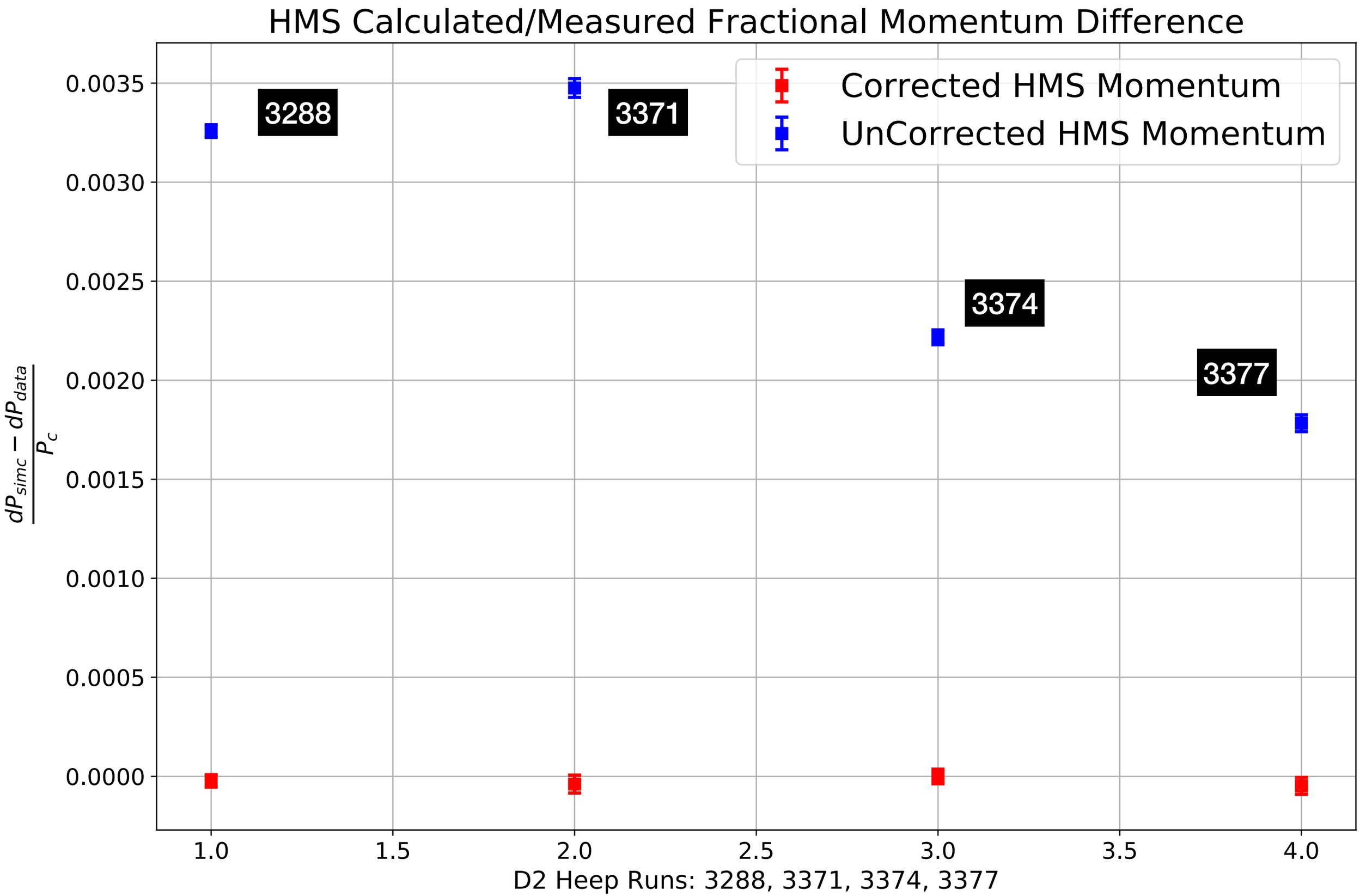








HMS Central Momentum Correction



SHMS Checks:

- ☑ **Is there any correlation between delta and focal plane quantities?**

- ☑ **Formula assumes HMS momentum is understood.**

$$E^{(e)}_{calc} \sim P^{(e)}_{calc} = E_b + M_p - E^{(p)}_{meas},$$

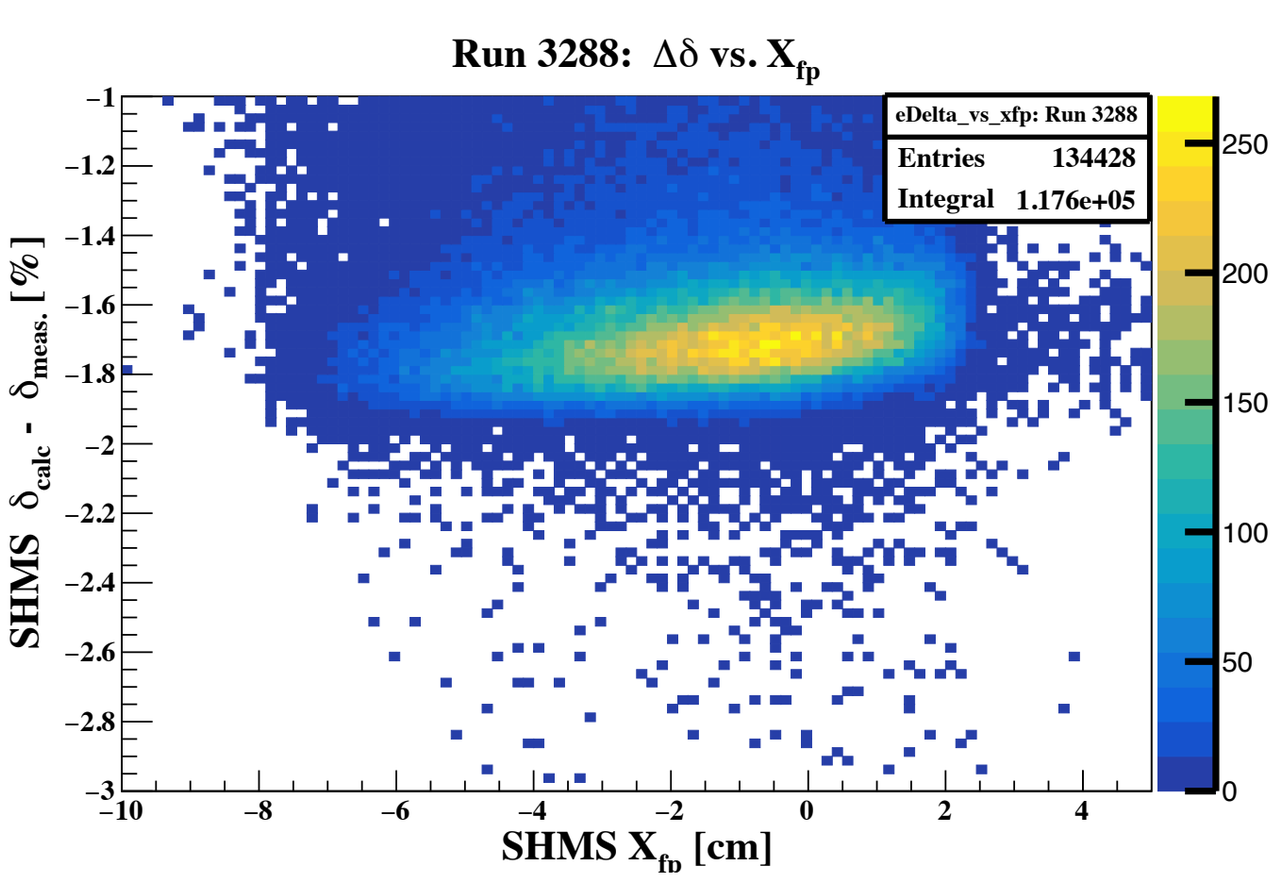
$$E^{(p)}_{meas} = \sqrt{M_p^2 + P^{(p)}_{meas}}$$

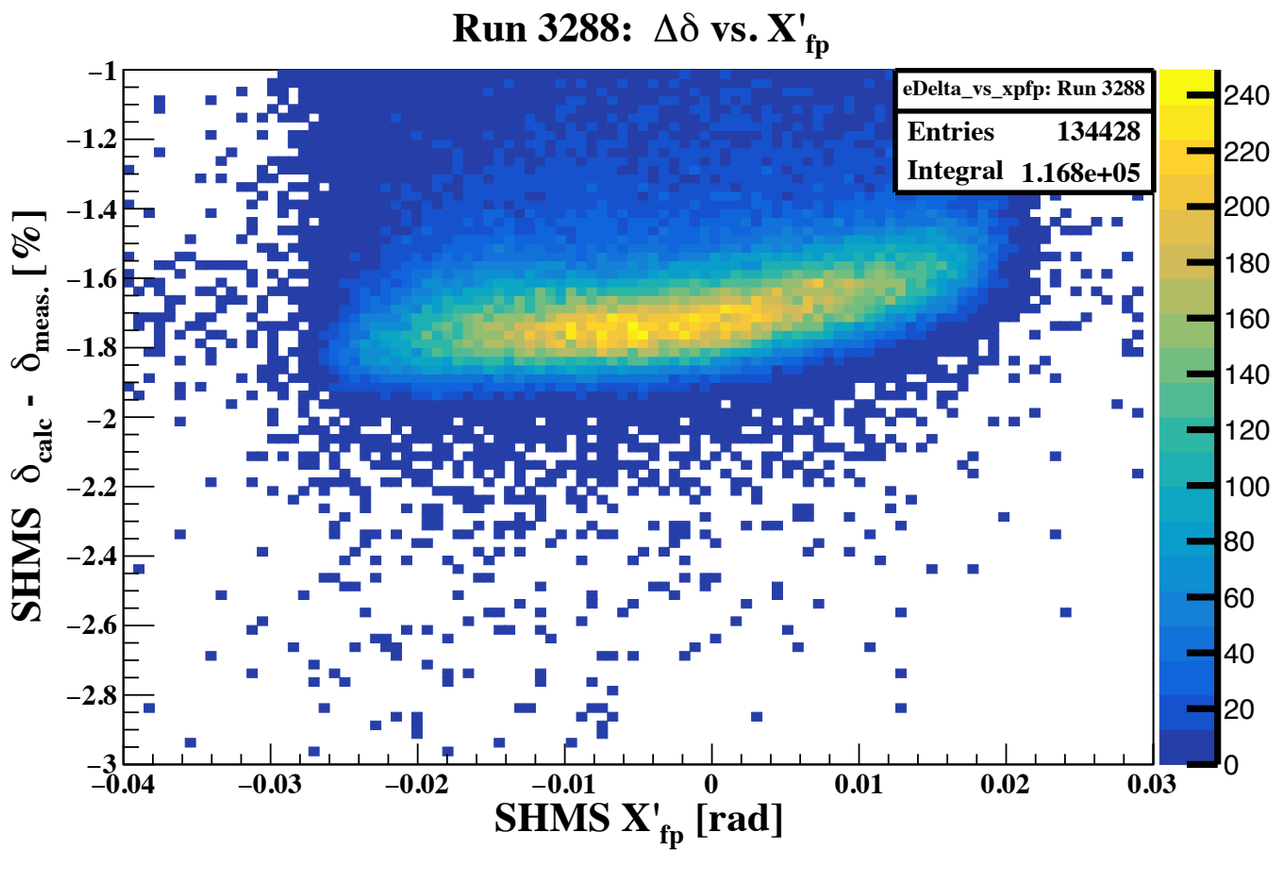
Calculated electron momentum

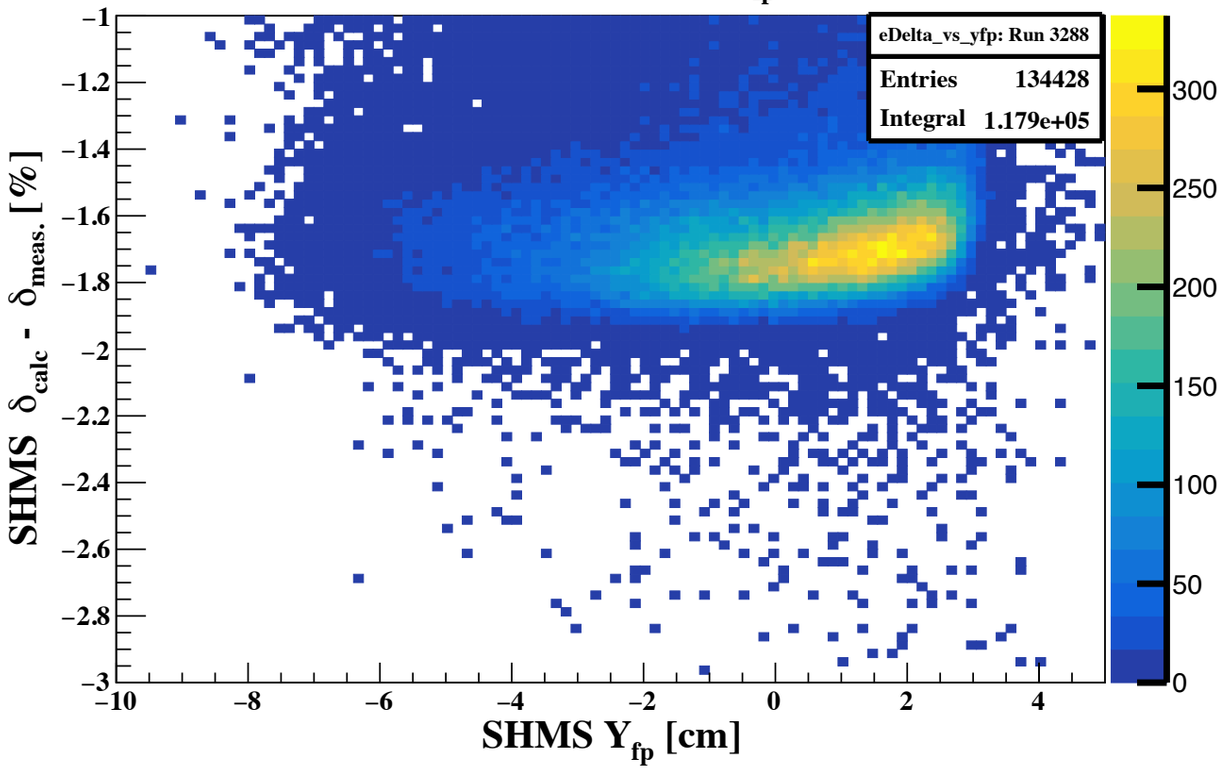
Measured proton momentum (in HMS)

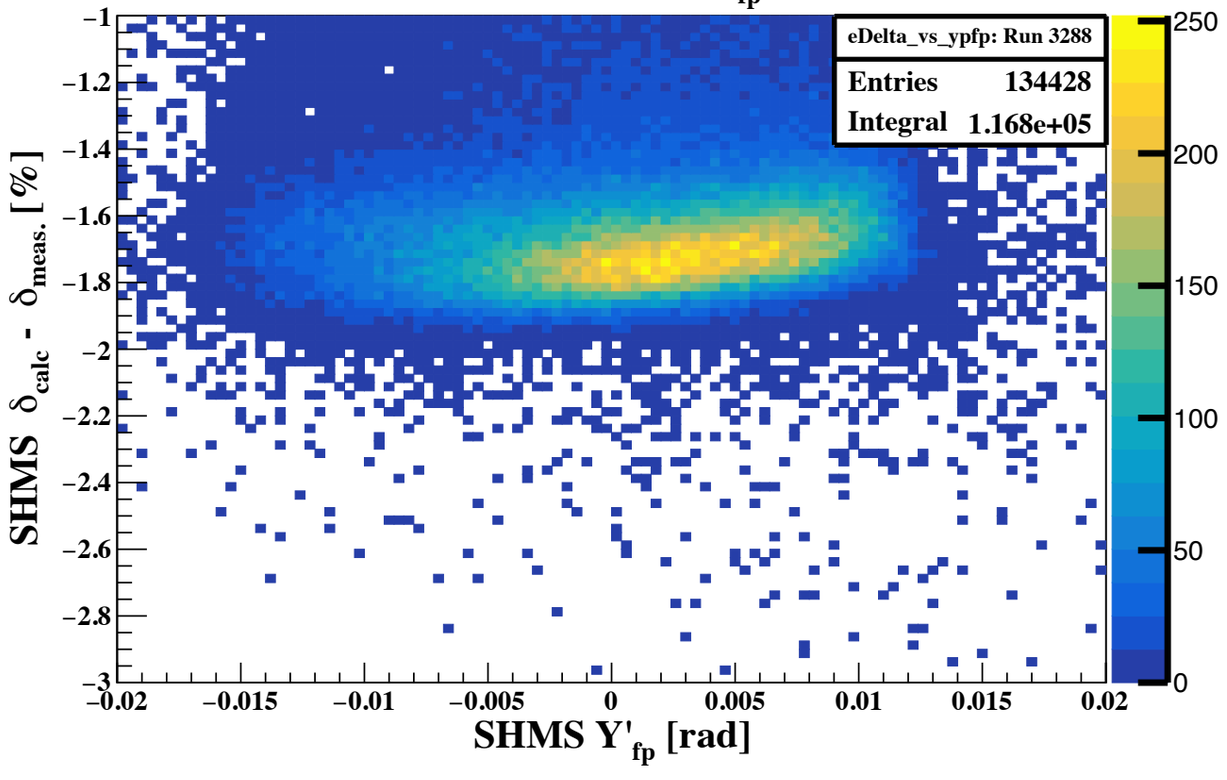
☑ Is there any correlation between delta and focal plane quantities?

CORRELATIONS OBSERVED !









Optimize the SHMS Delta Component

- ☑ **Observed correlations indicate delta reconstruction is NOT optimized.**

- ☑ **Reconstructed events at the target are smeared out resulting in poor resolution of Missing Energy, Invariant Mass W, etc.**

- ☑ **Fit the calculated/measured delta difference vs. focal plane**

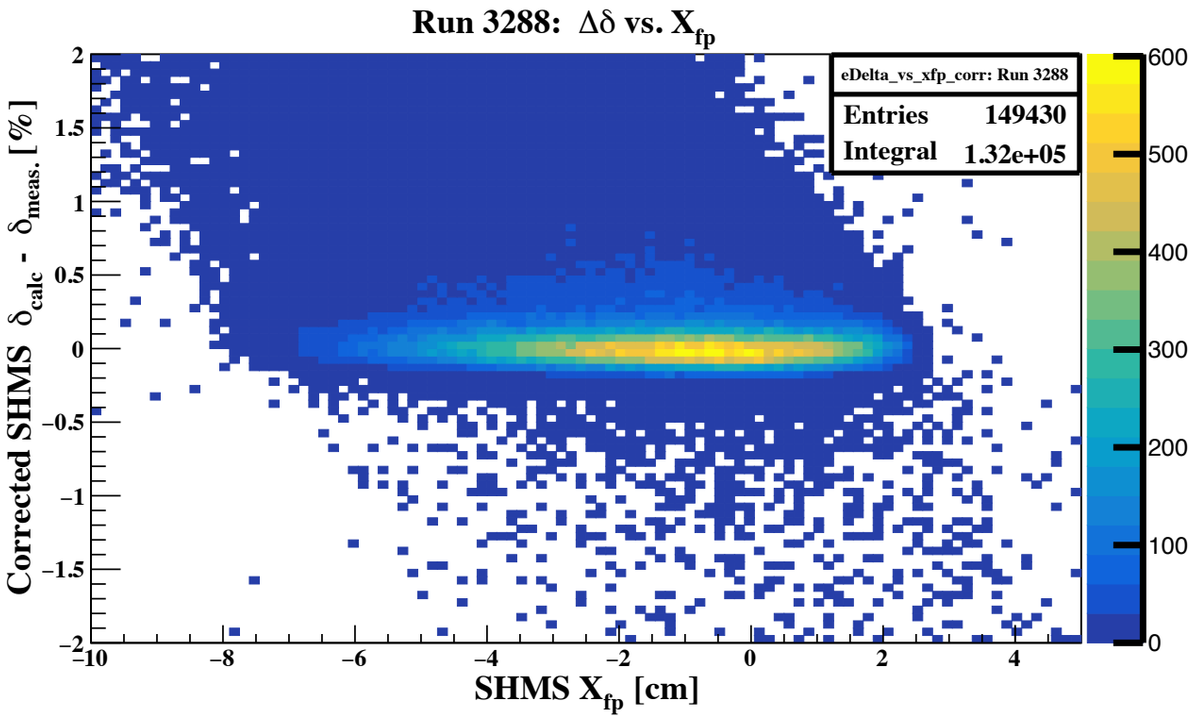
$$\Delta\delta = \delta_{calc} - \delta_{meas} = D_0 + D1x_{fp} + D_2x'_{fp} + D_3y_{fp} + D_4y'_{fp} + f(\mathcal{O}^2)$$

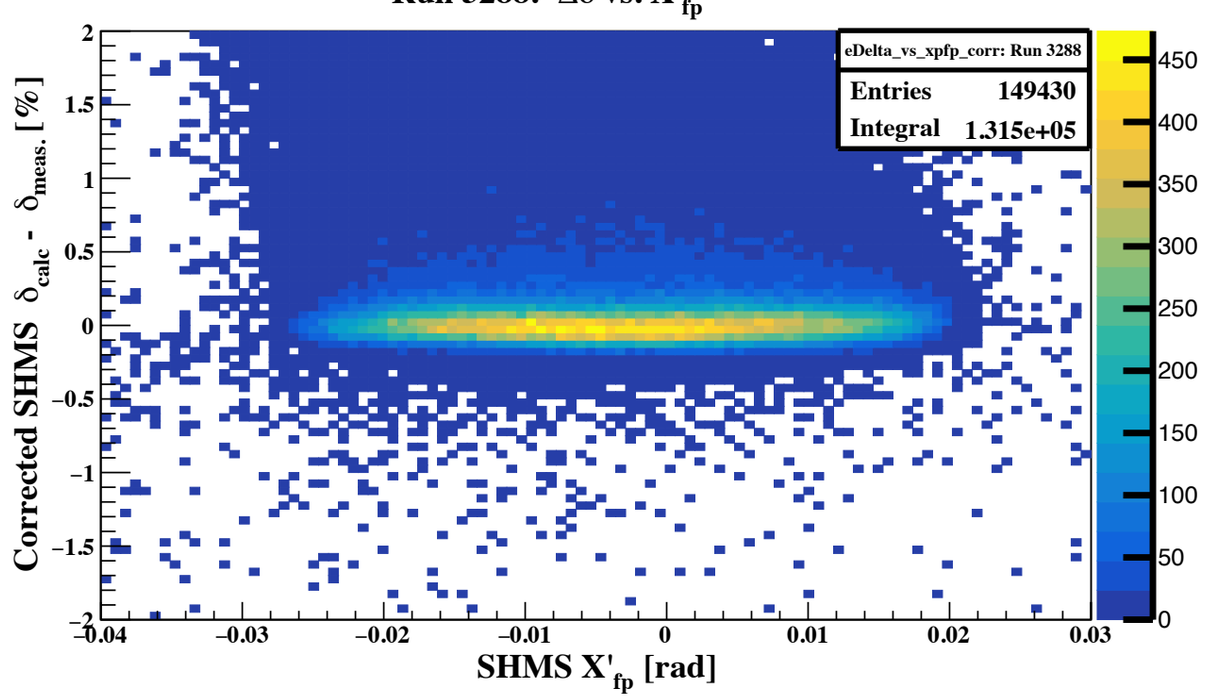
D_i : matrix coefficients to be minimized

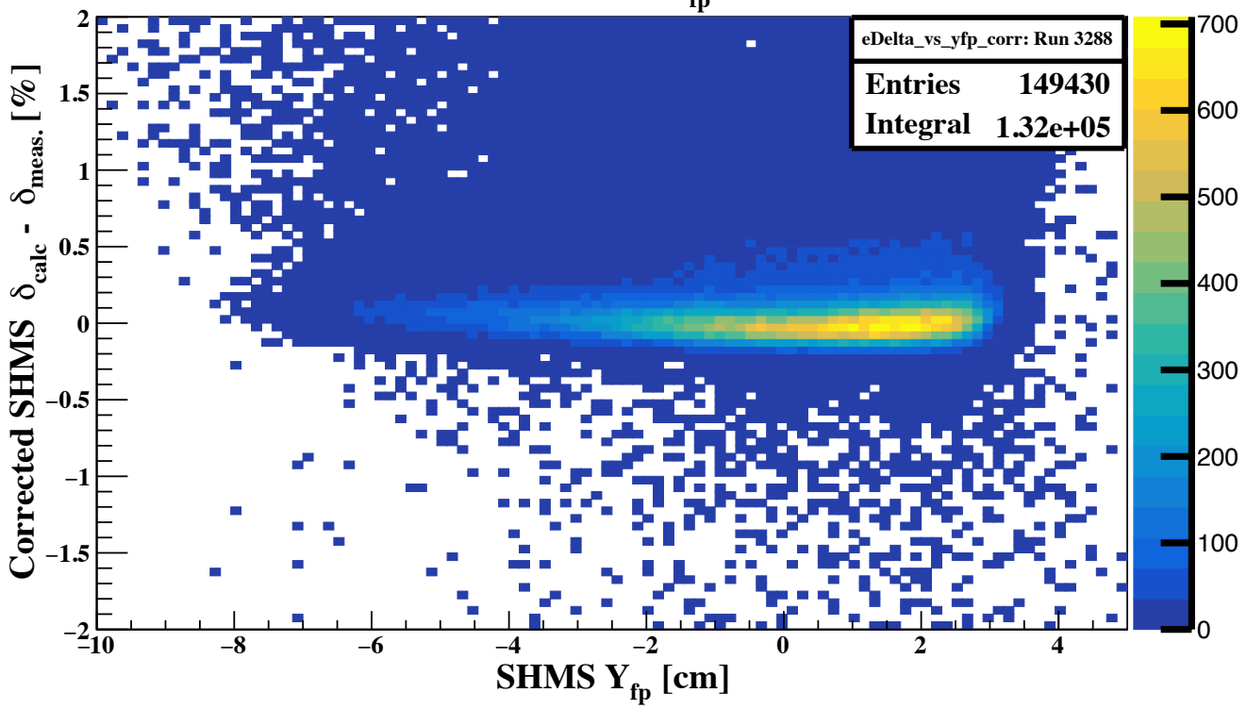
- ☑ **Update optics matrix file with new coefficients.**

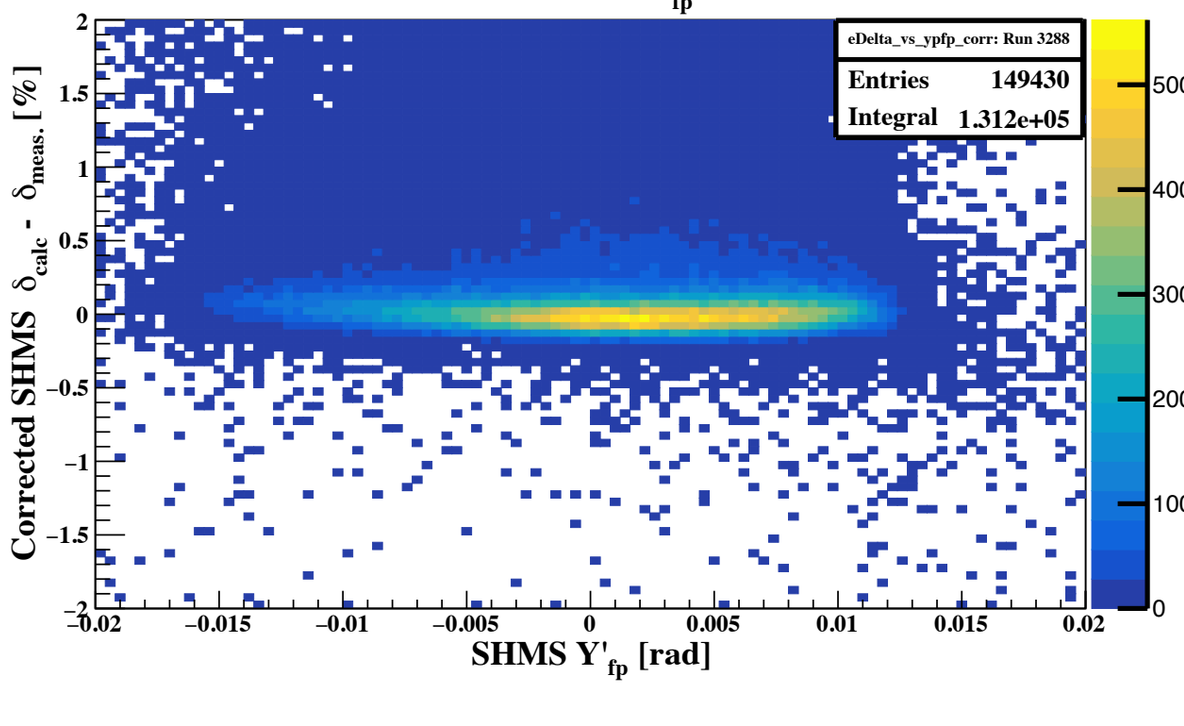
Optimized SHMS Delta Matrix

☑ **NO CORRELATIONS OBSERVED !**

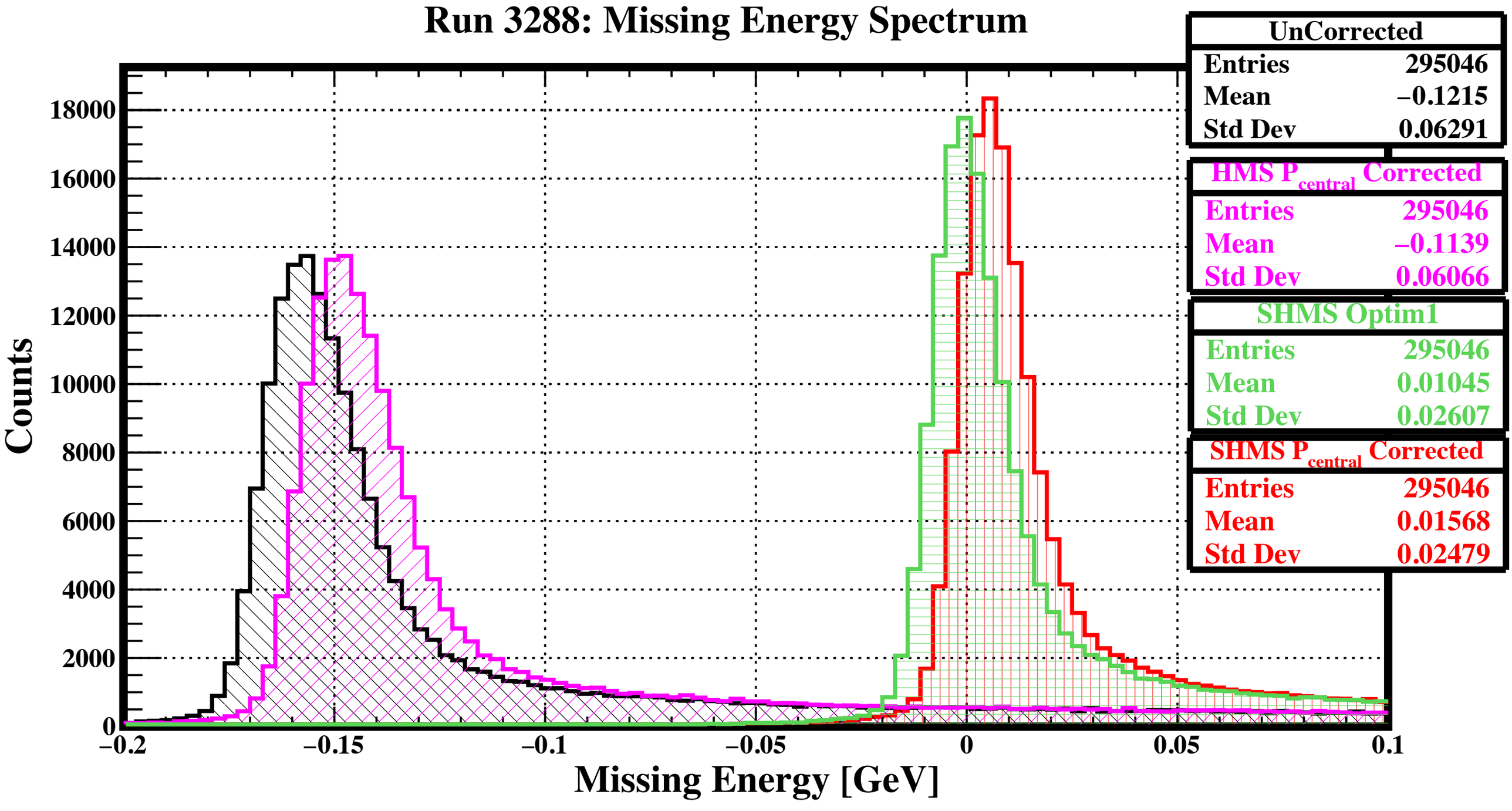




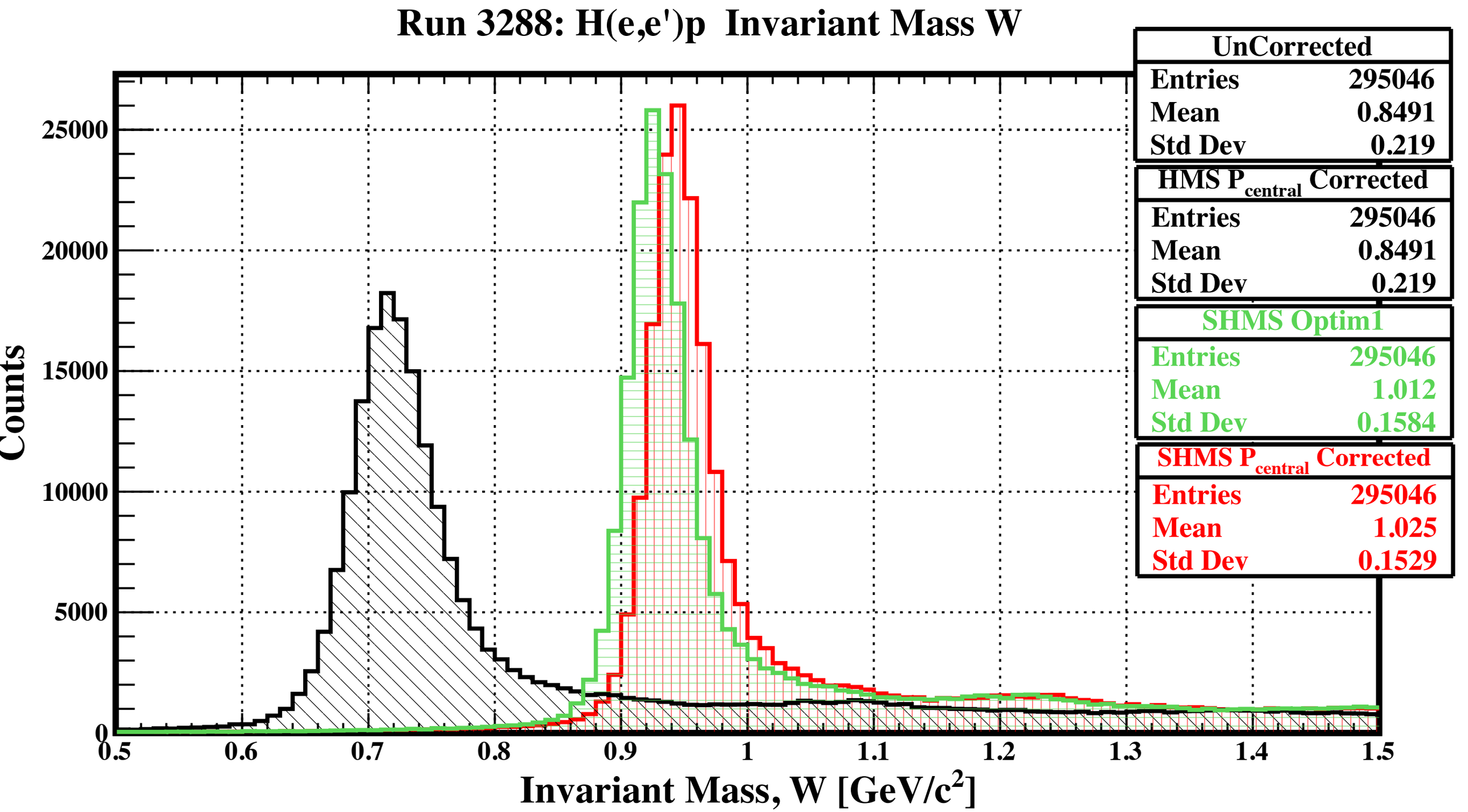




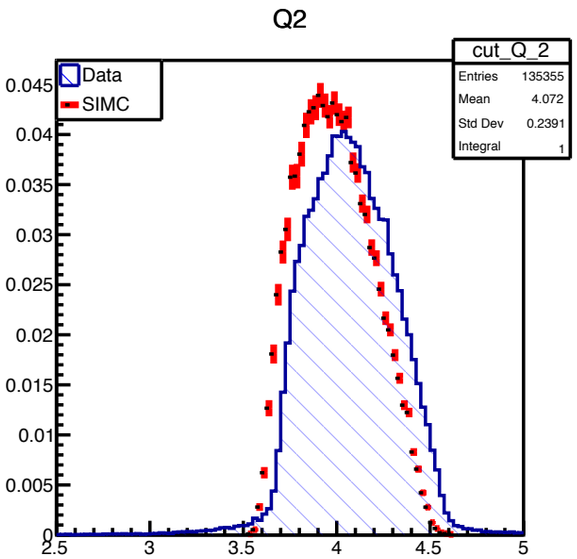
Results of HMS/SHMS Momentum Corrections

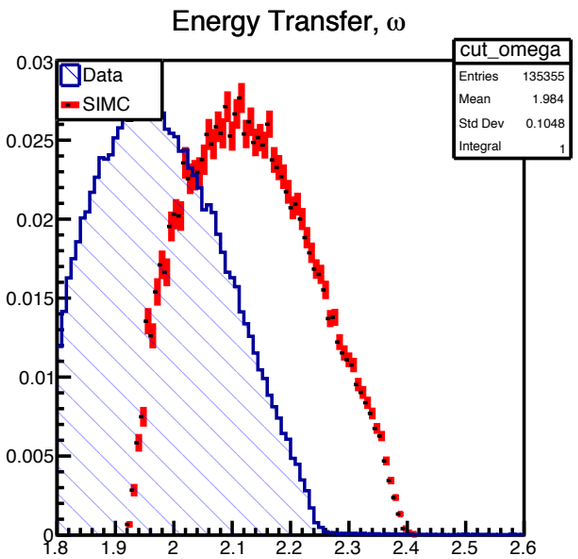


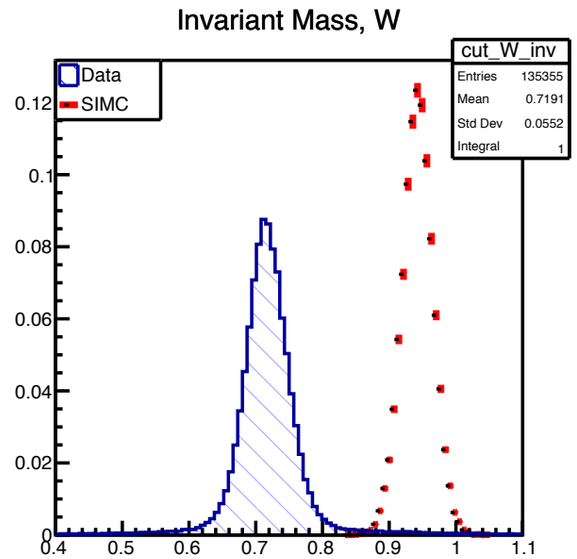
Results of HMS/SHMS Momentum Corrections

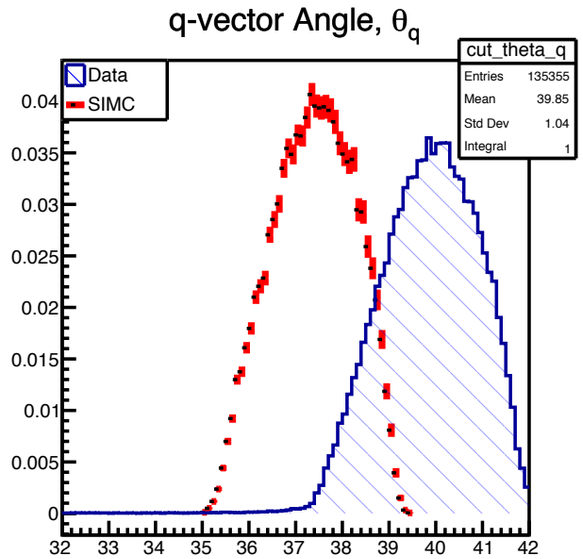


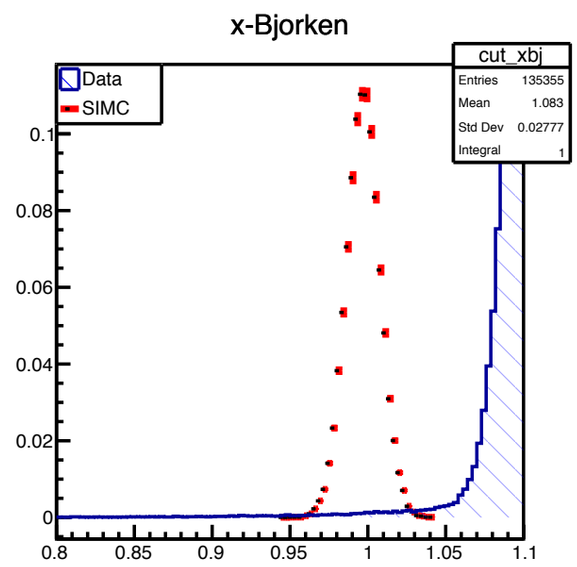
SIMC/DATA Comparison
BEFORE HMS/SHMS Optimization

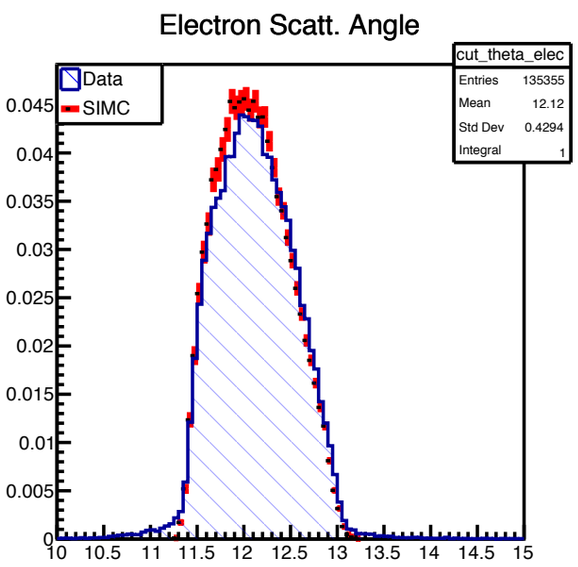


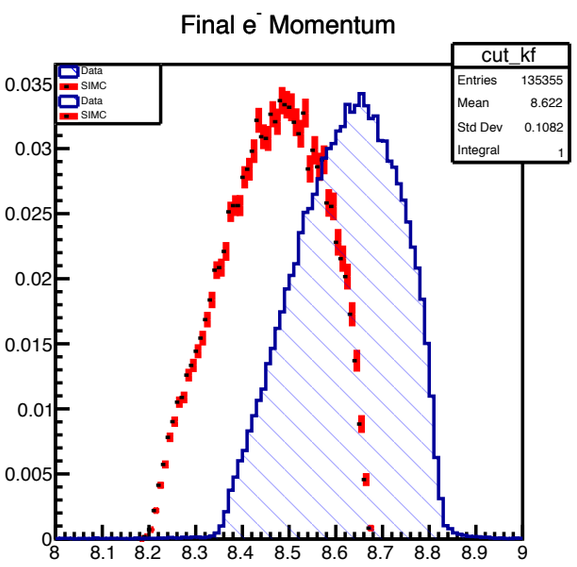


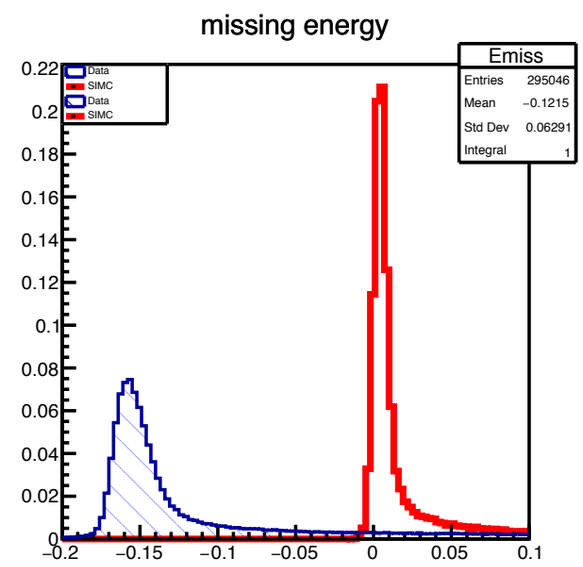




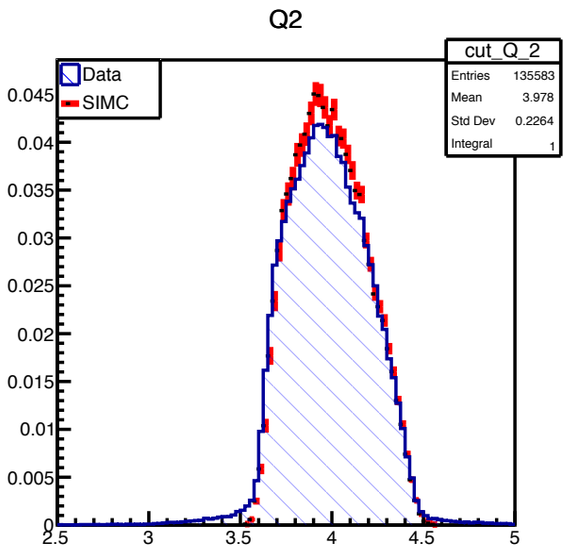


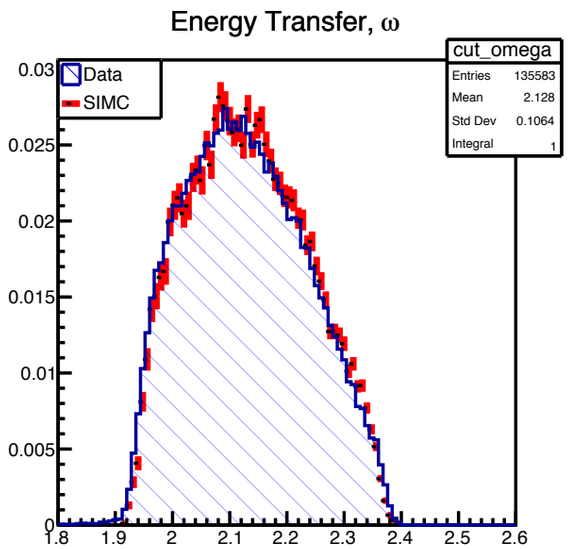


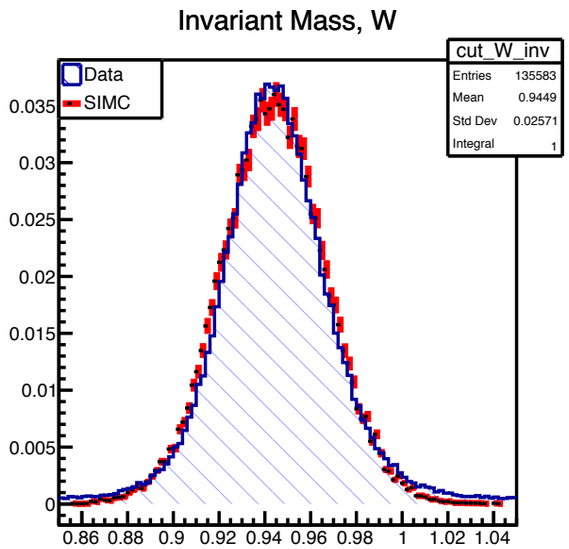


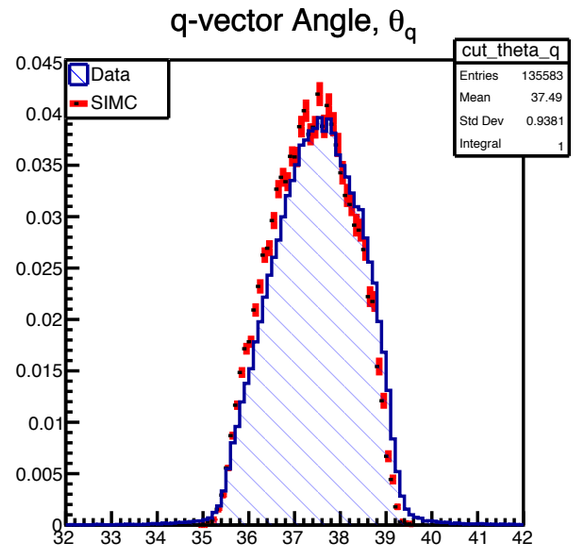


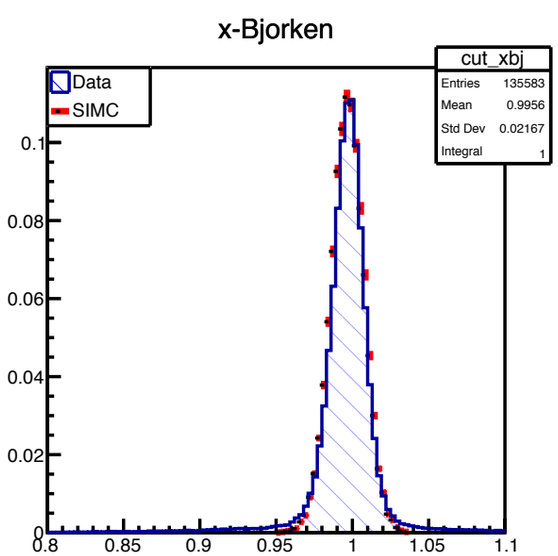
SIMC/DATA Comparison
AFTER HMS/SHMS Optimization

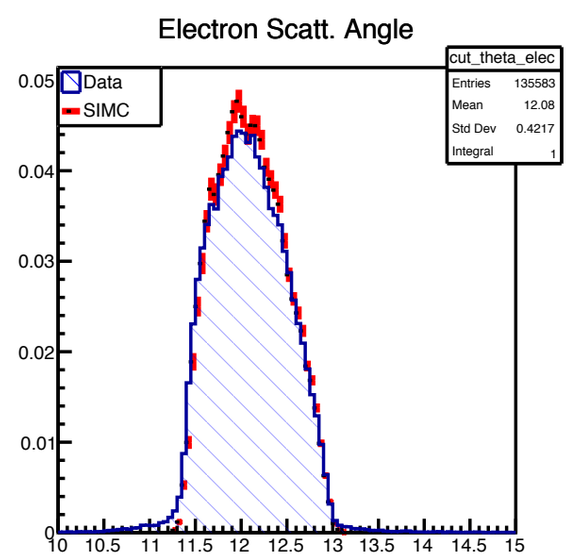


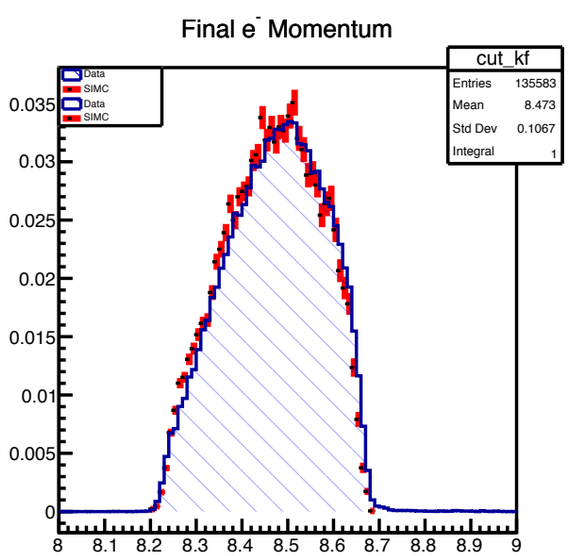


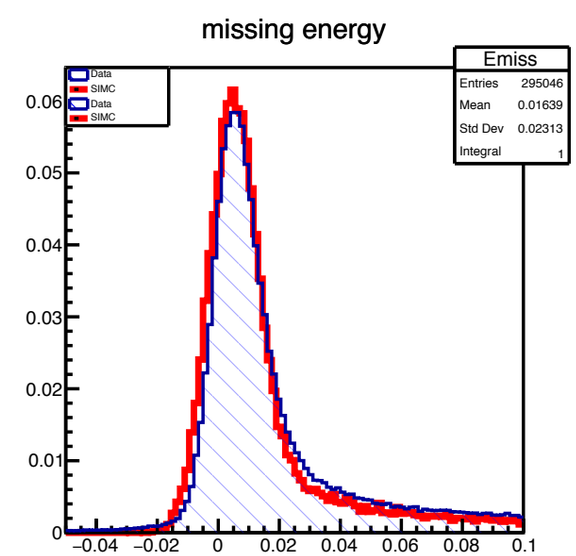












Summary

- ☑ H(e,e'p) Analysis for E12-10-003 ALMOST completed !
- ☑ HMS Momentum for D2 kinematics is understood.
- ☑ SHMS Momentum for D2 kinematics is understood.
- ☑ SHMS Delta component of optics has been optimized
- ☐ SIMC/DATA Yields is currently being studied.
  (See BackUp Slides)

Thank You!

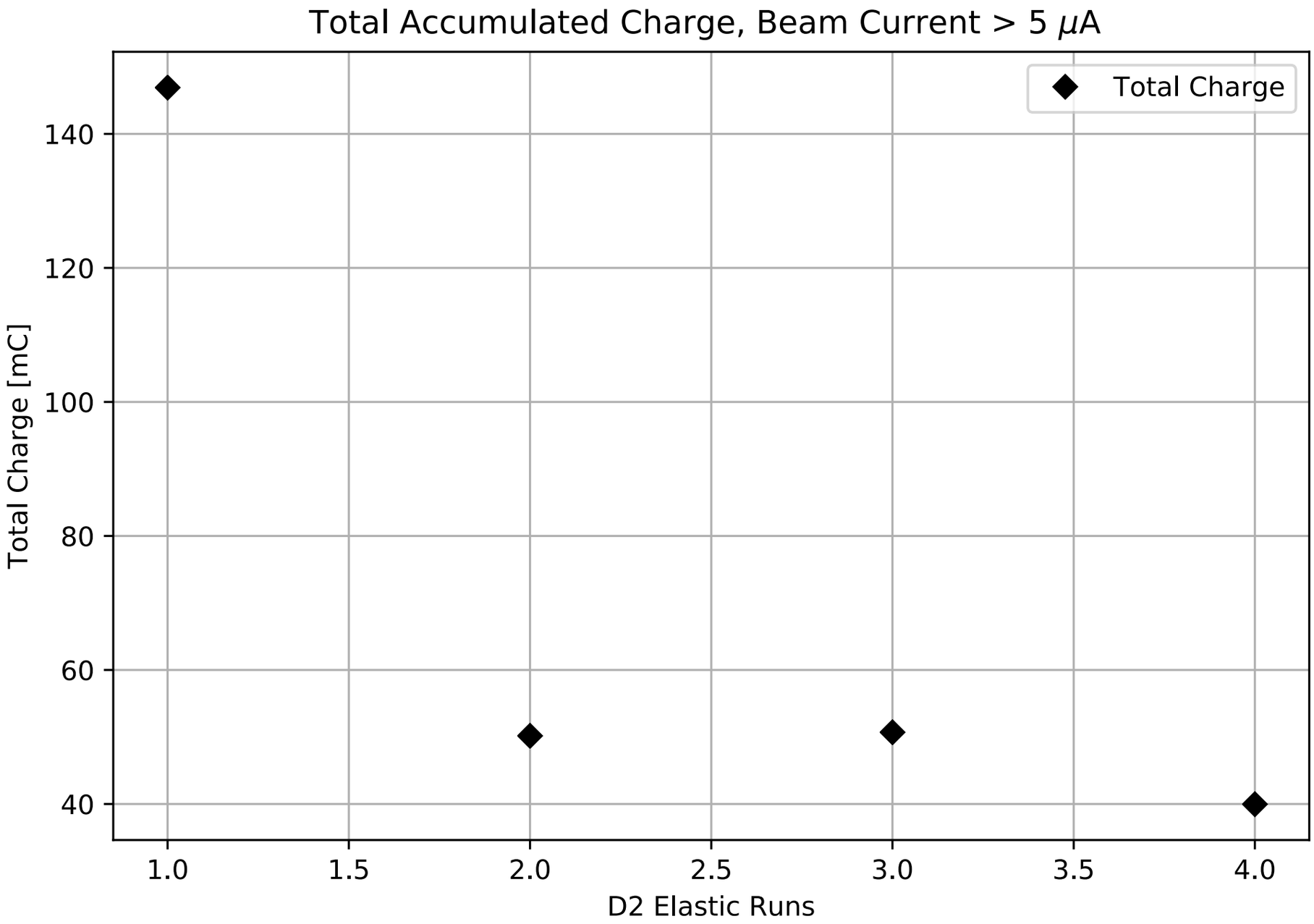
Questions?

Backup Slides

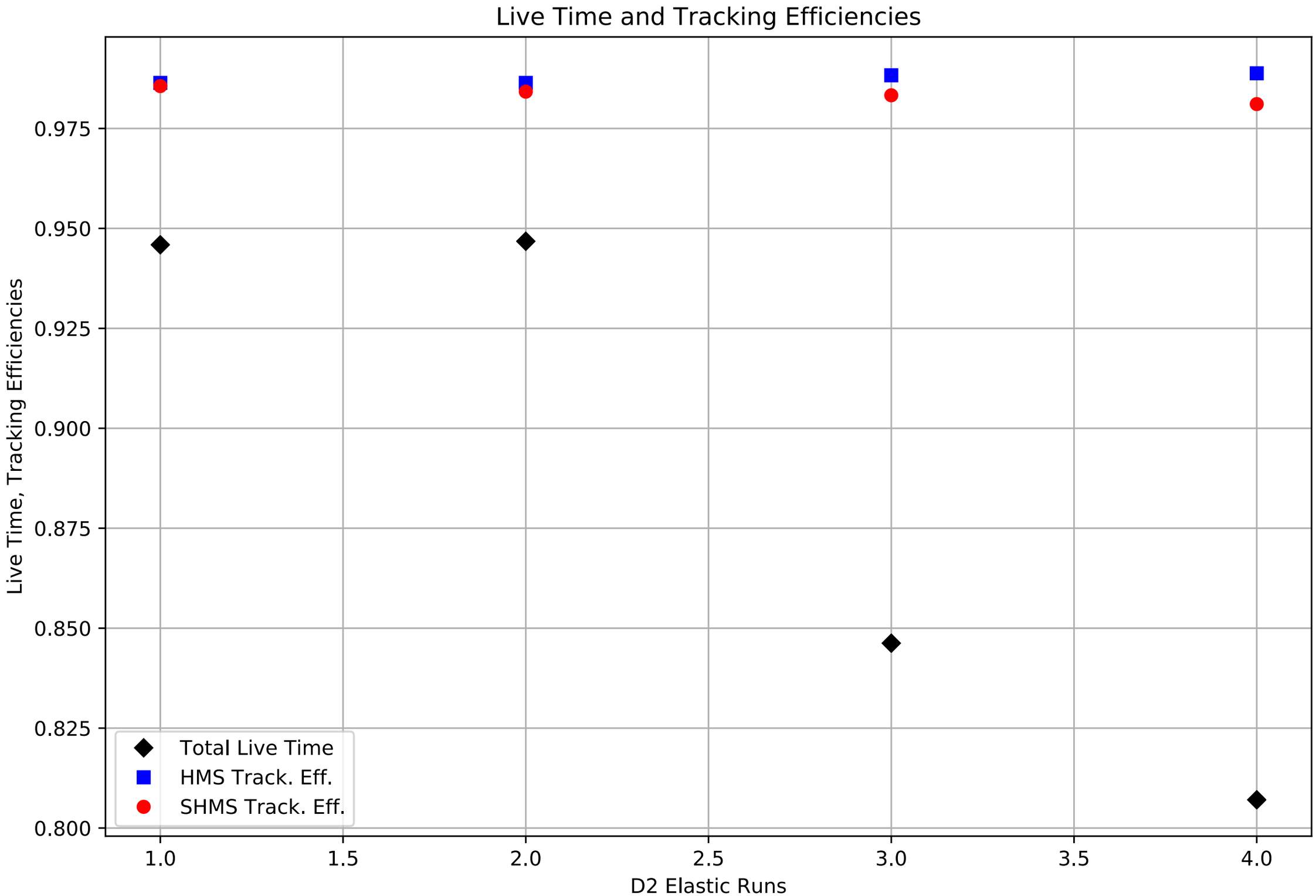
SIMC Weighted Yield Calculation:

$$Y^{Corr} = Y^{Uncorr} * \text{FullWeight}$$

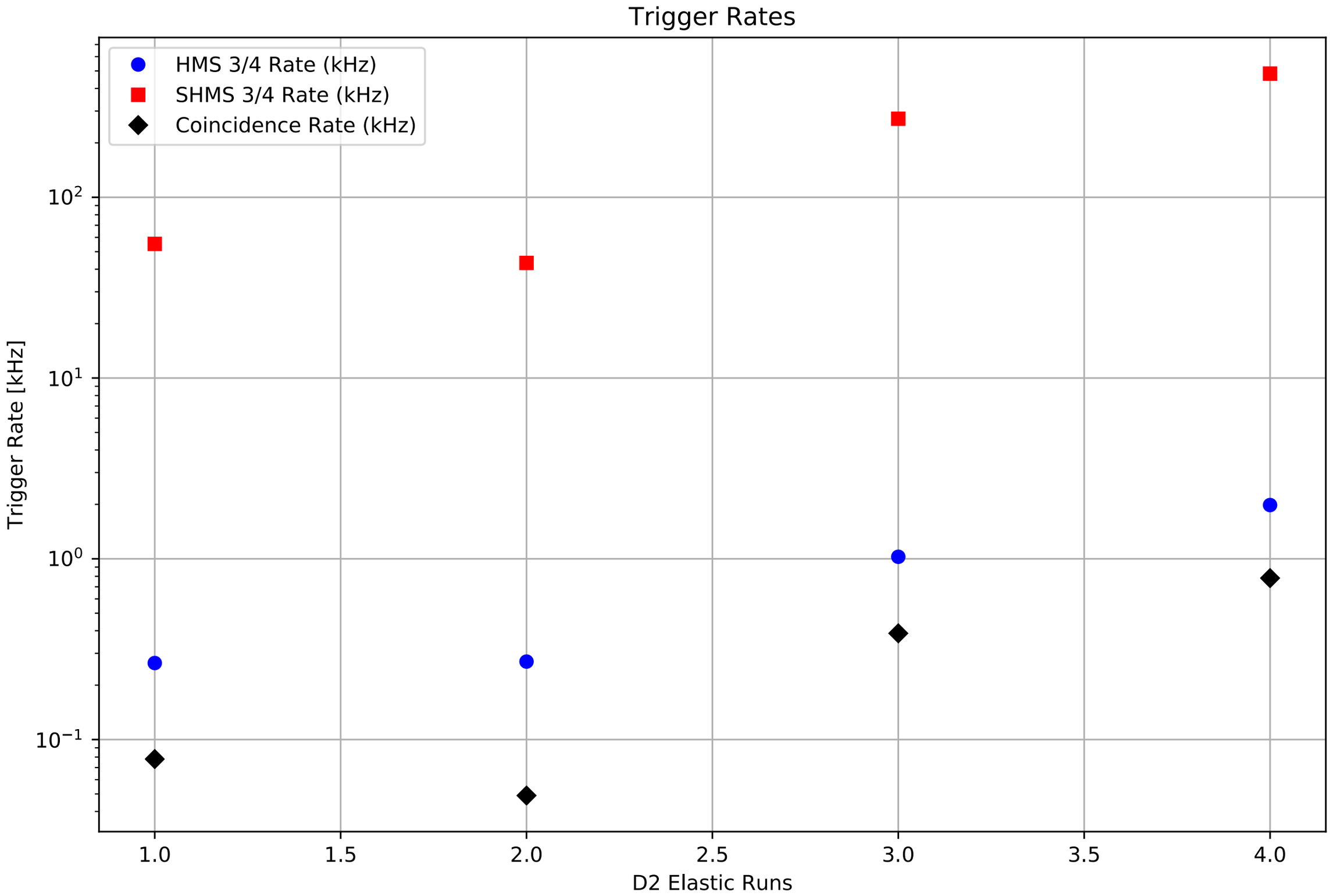
$$\text{Full Weight} = \frac{N_{norm} * \sigma_{weight} * Q_{charge} * \epsilon_{trk}^{(e)} * \epsilon_{trk}^{(h)} * L.T.}{\text{entries}}$$



Live Time and Tracking Efficiency

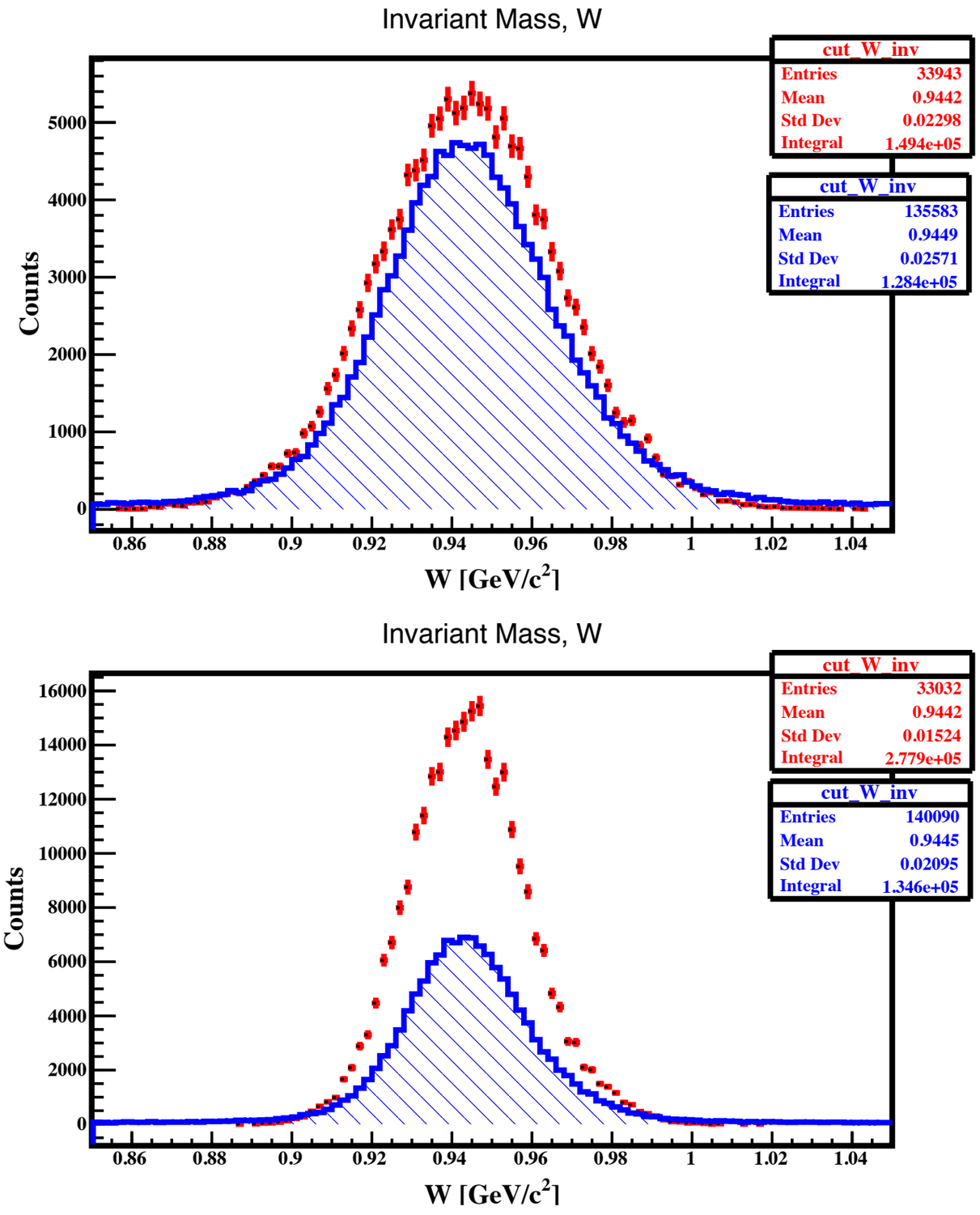


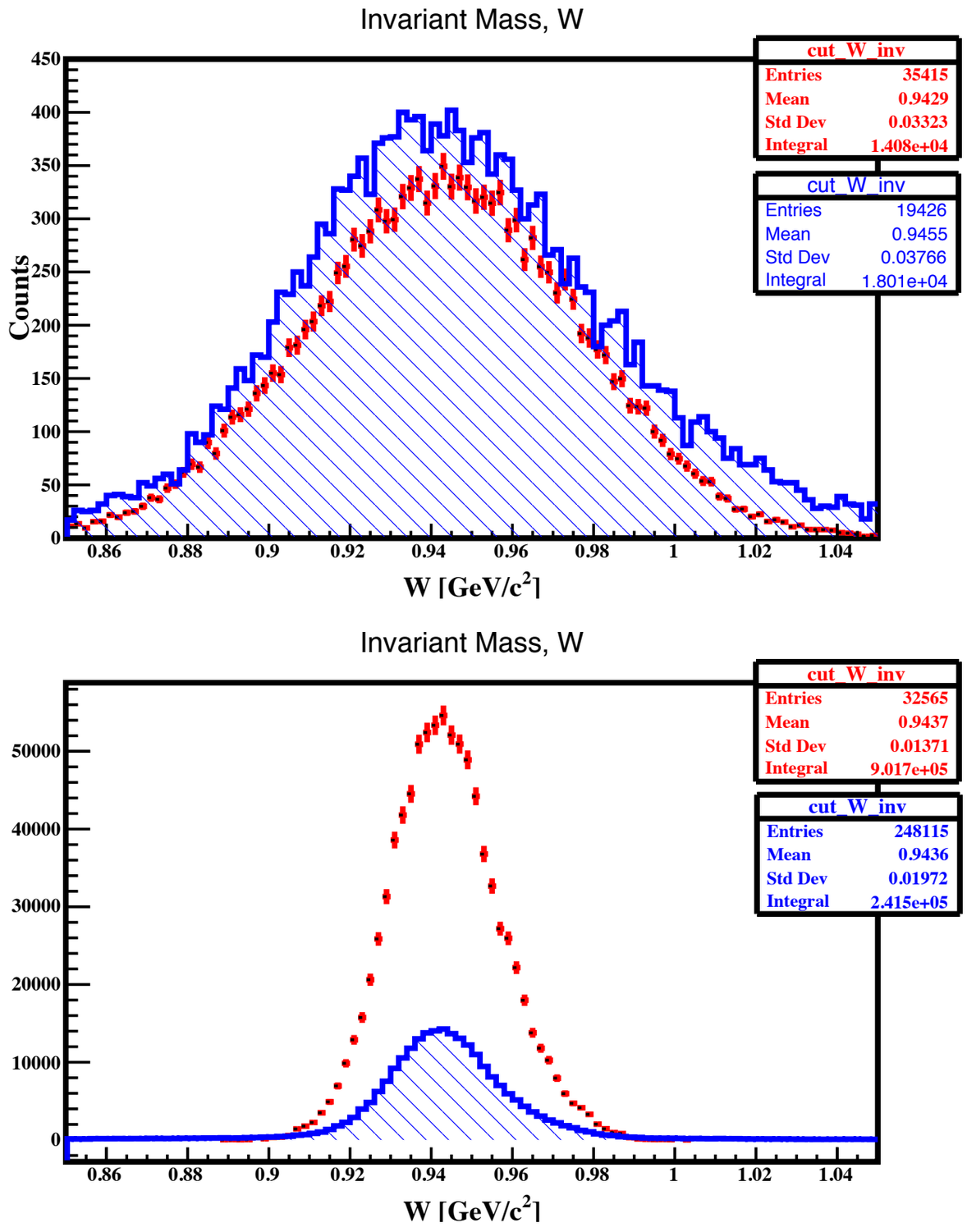
Trigger Rates



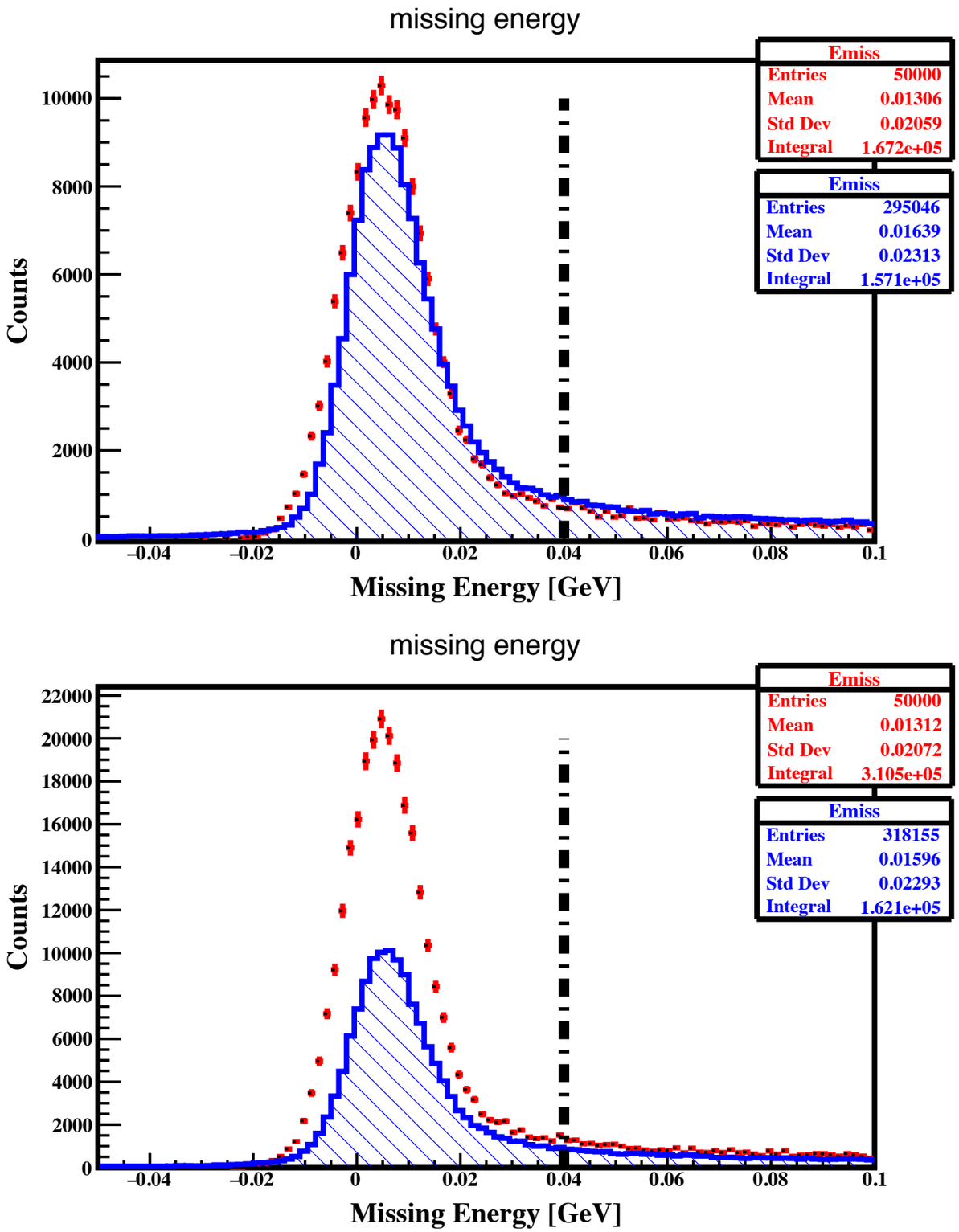
Weighted SIMC/DATA Comparison

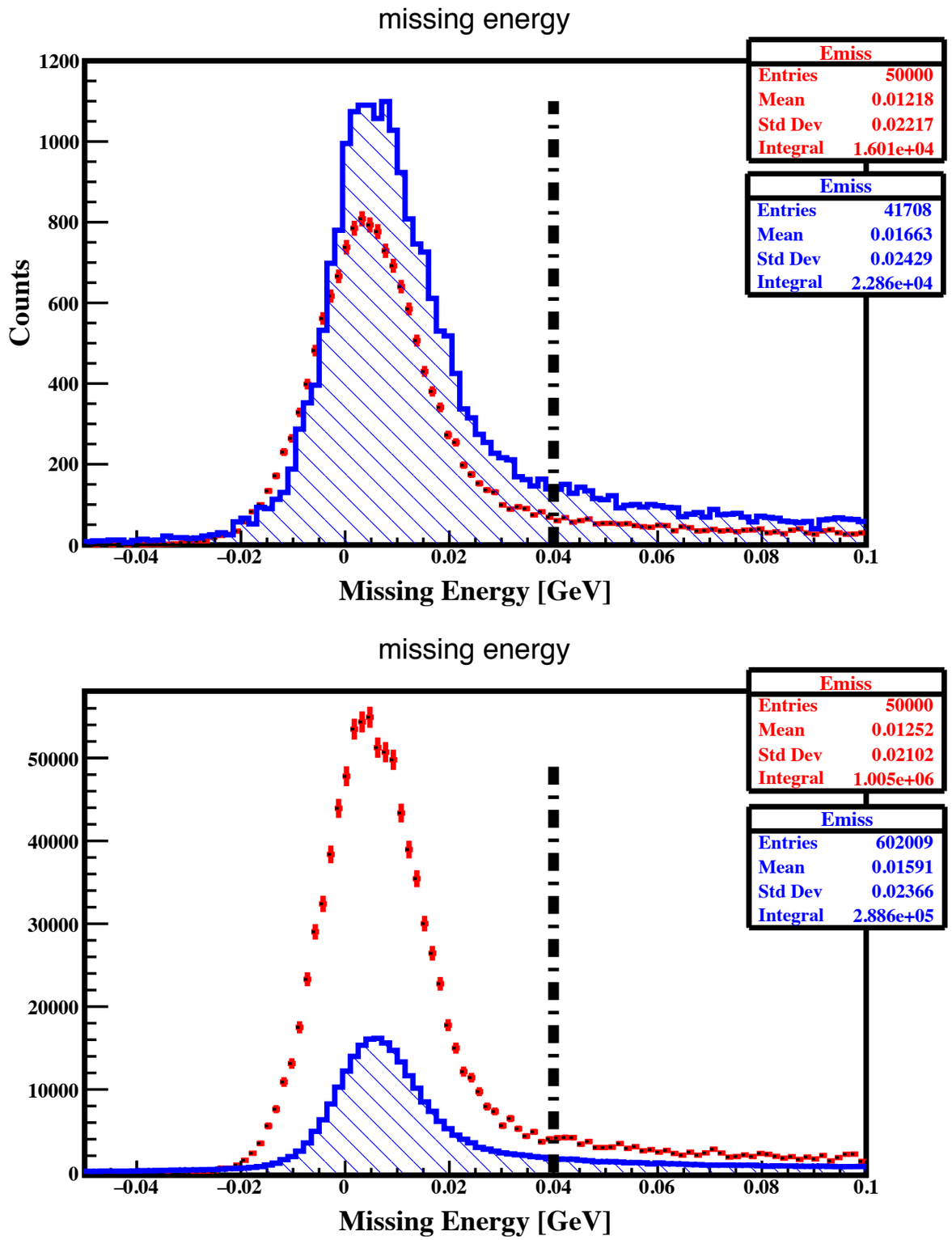
☑ **Why is SIMC yield much larger than DATA yield for the bottom two runs?**



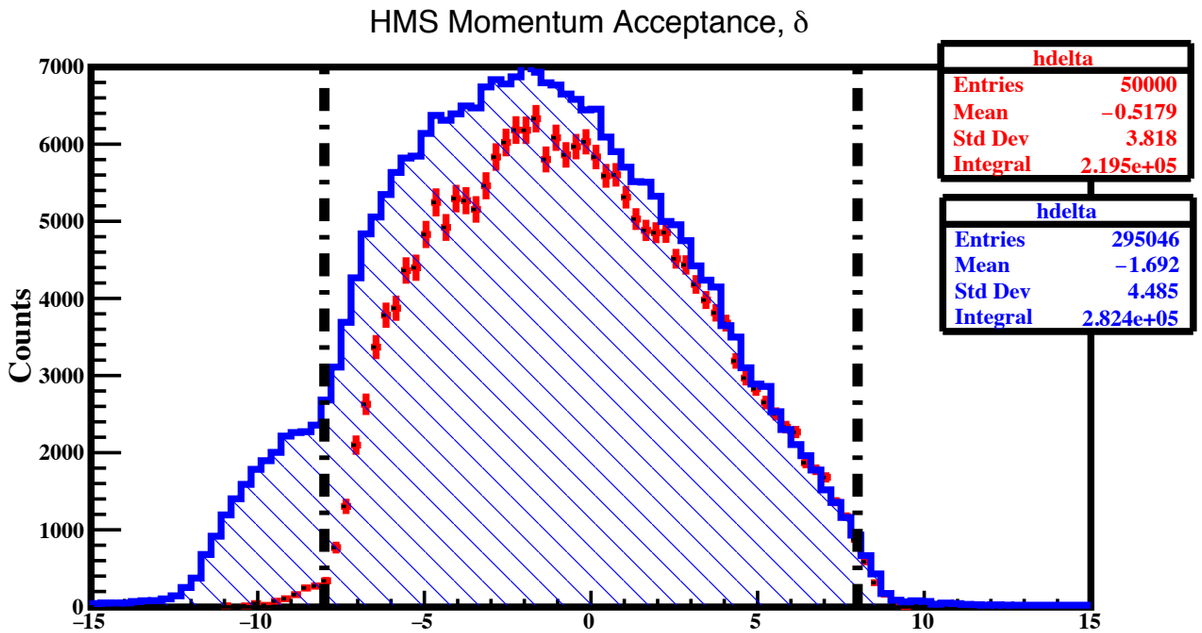


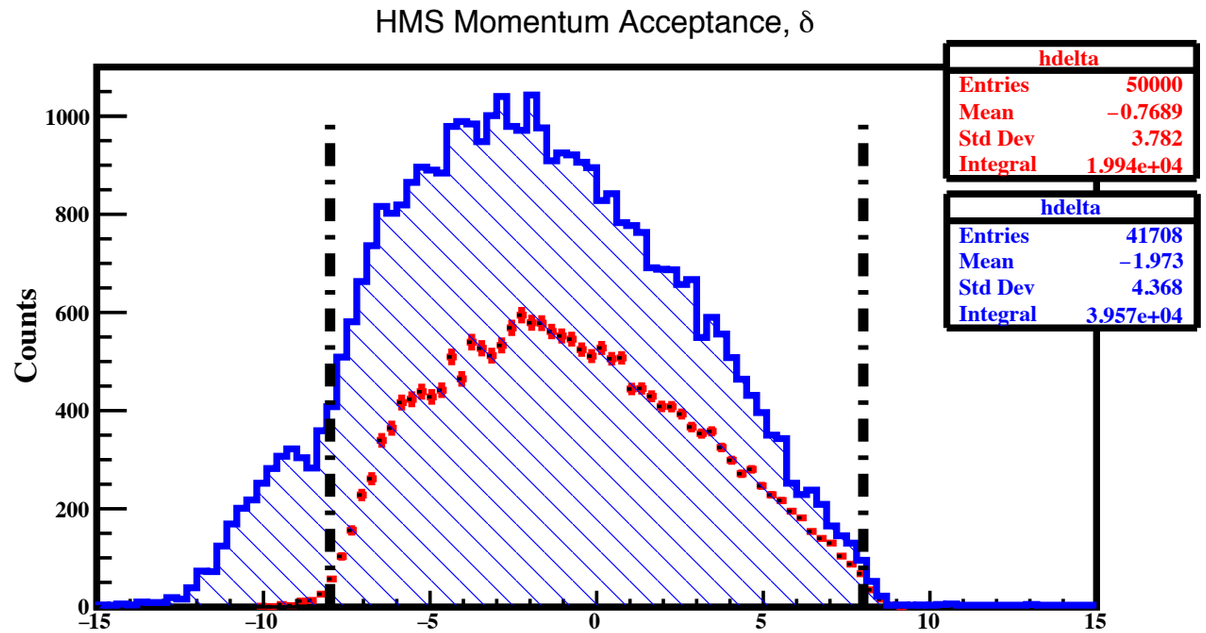
Weighted SIMC/DATA Comparison: CUTS APPLIED, Missing Energy < 40 MeV

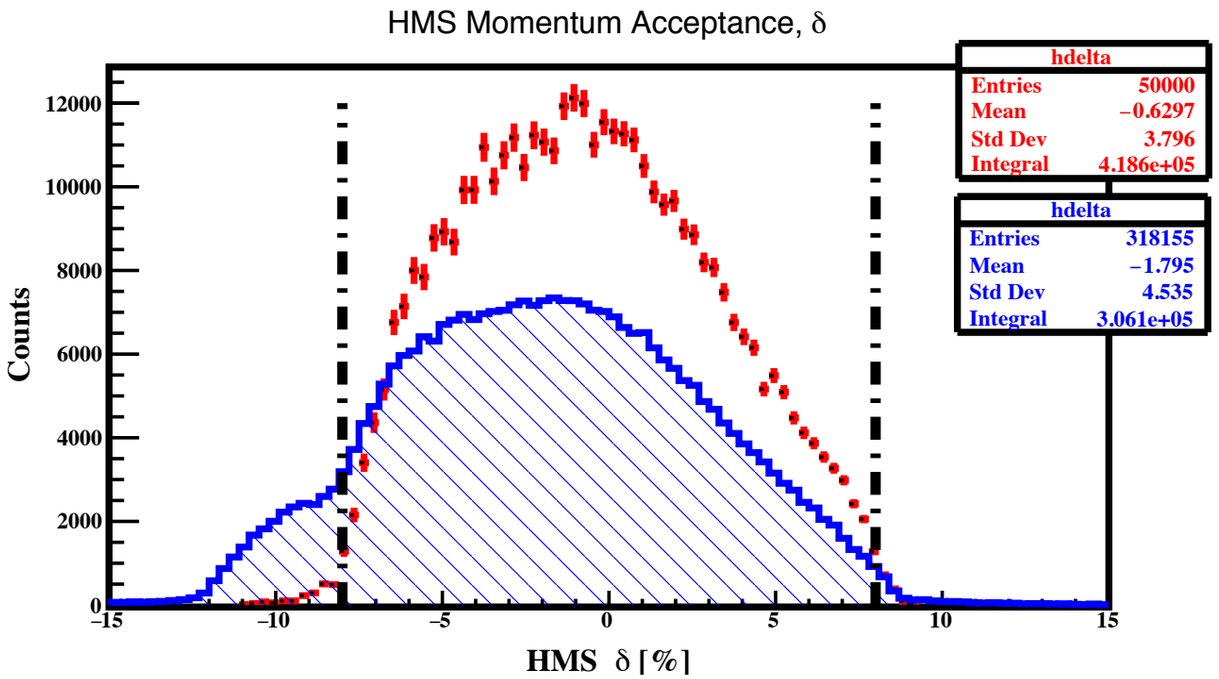


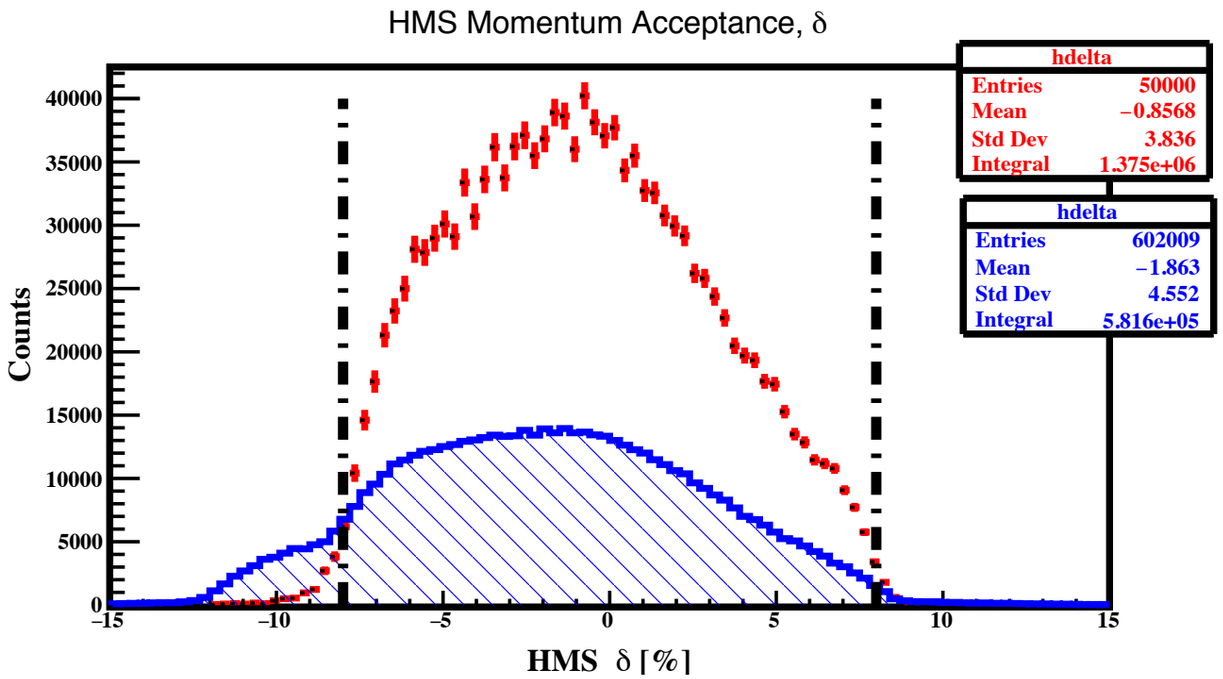


Weighted SIMC/DATA Comparison: CUTS APPLIED, HMS Delta (-8,8)%









Weighted SIMC/DATA Comparison: CUTS APPLIED, SHMS Delta (-10,22)%