

# CaFe H(e, e'p) Centroid Kinematics Alignment

## Summary

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# Definitions

calculated (e-) momentum

$$k_{f,calc}(E_b, \theta_e) = \frac{M_p E_b}{M_p + 2E_b \sin^2(\theta_e/2)}$$

measured (e-) momentum

$$k_{f,meas} = P_0 \left( \frac{\delta_{shms}}{100} + 1 \right)$$

calculated (proton) momentum

$$P_{f,z} = E_b - k_f \cos(\theta_e)$$

$$P_{f,x} = -k_f \sin(\theta_e)$$

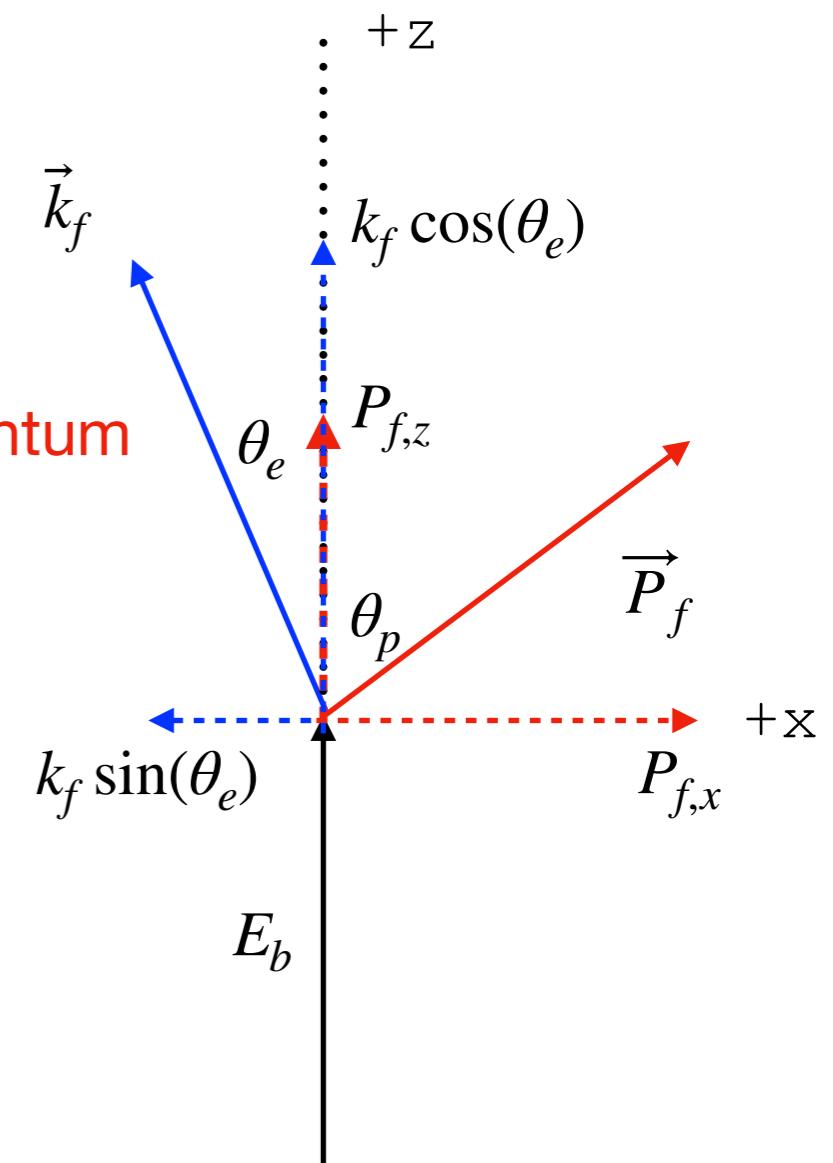
$$P_{f,calc}(E_b, \theta_e) = \sqrt{P_{f,x}^2 + P_{f,z}^2}$$

calculated (proton) angle

$$\theta_{p,calc}(E_b, \theta_e) = \tan^{-1} \frac{P_{f,x}}{P_{f,z}}$$

measured (proton) momentum

$$P_{f,meas} = P_0 \left( \frac{\delta_{hms}}{100} + 1 \right)$$



calculated-measured:

$$dk_f = k_{f,calc} - k_{f,meas}$$

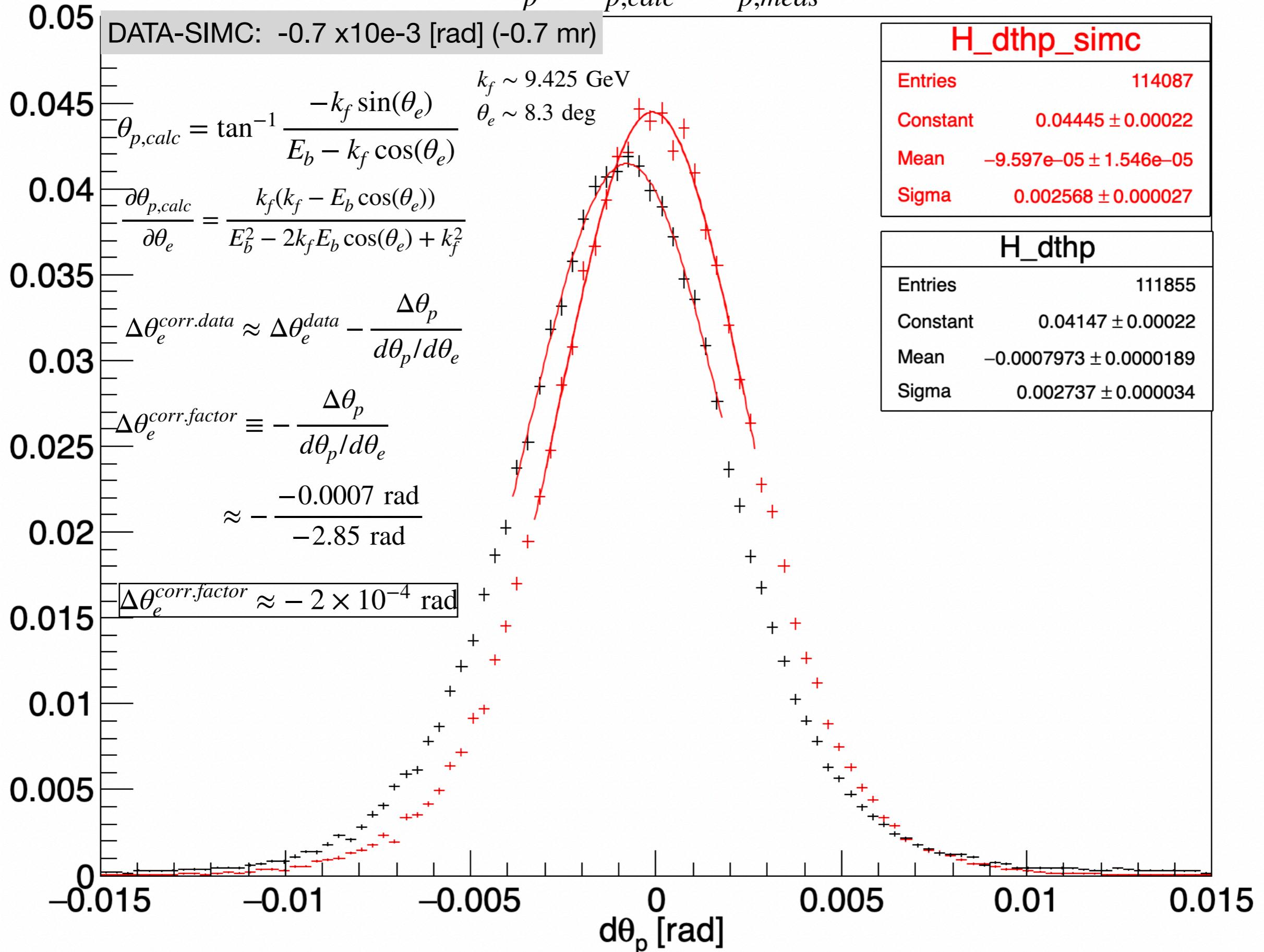
$$dP_f = P_{f,calc} - P_{f,meas}$$

$$d\theta_p = \theta_{p,calc} - \theta_{p,meas}$$

All calculated quantities are derived from electron (e-) beam energy and (e-) angle (assumed well known)

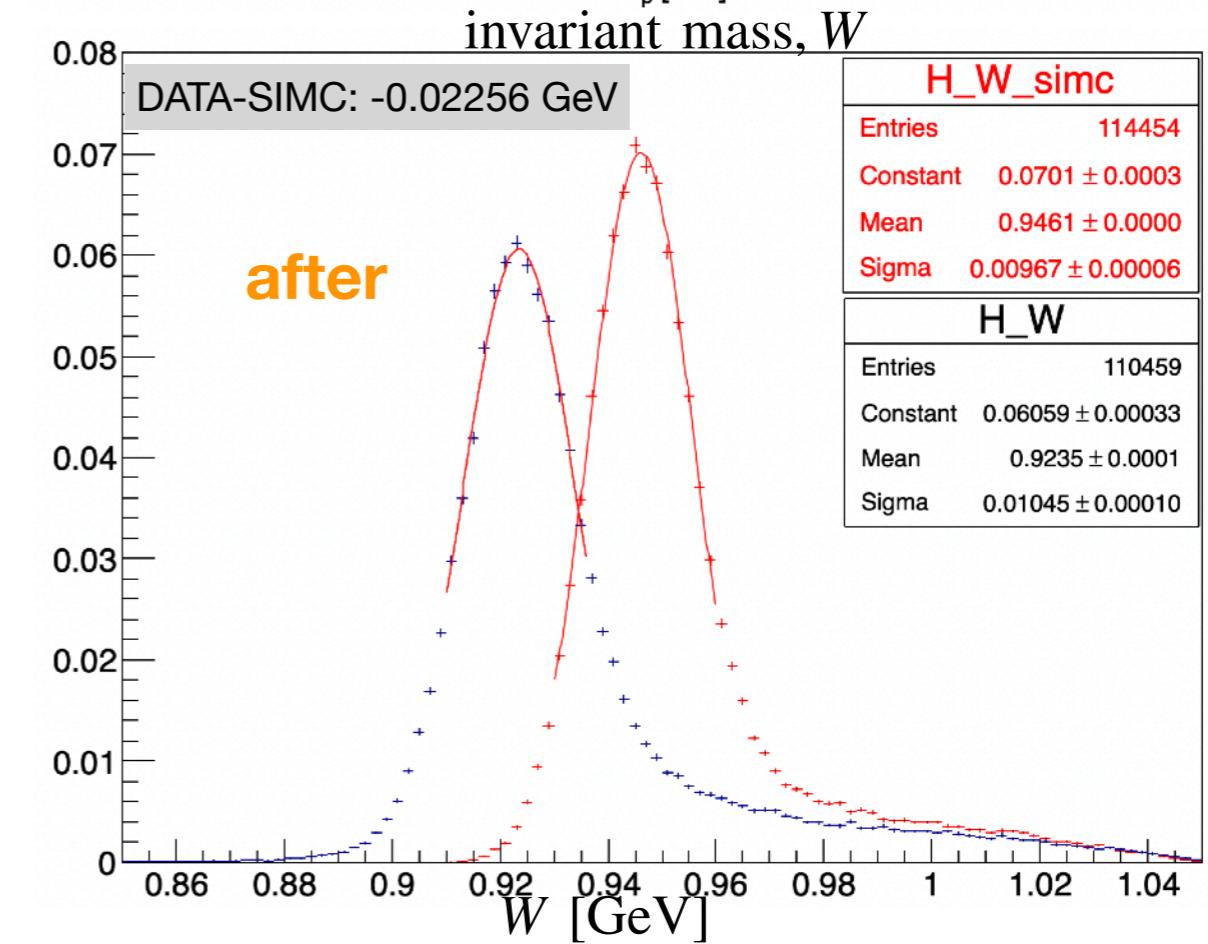
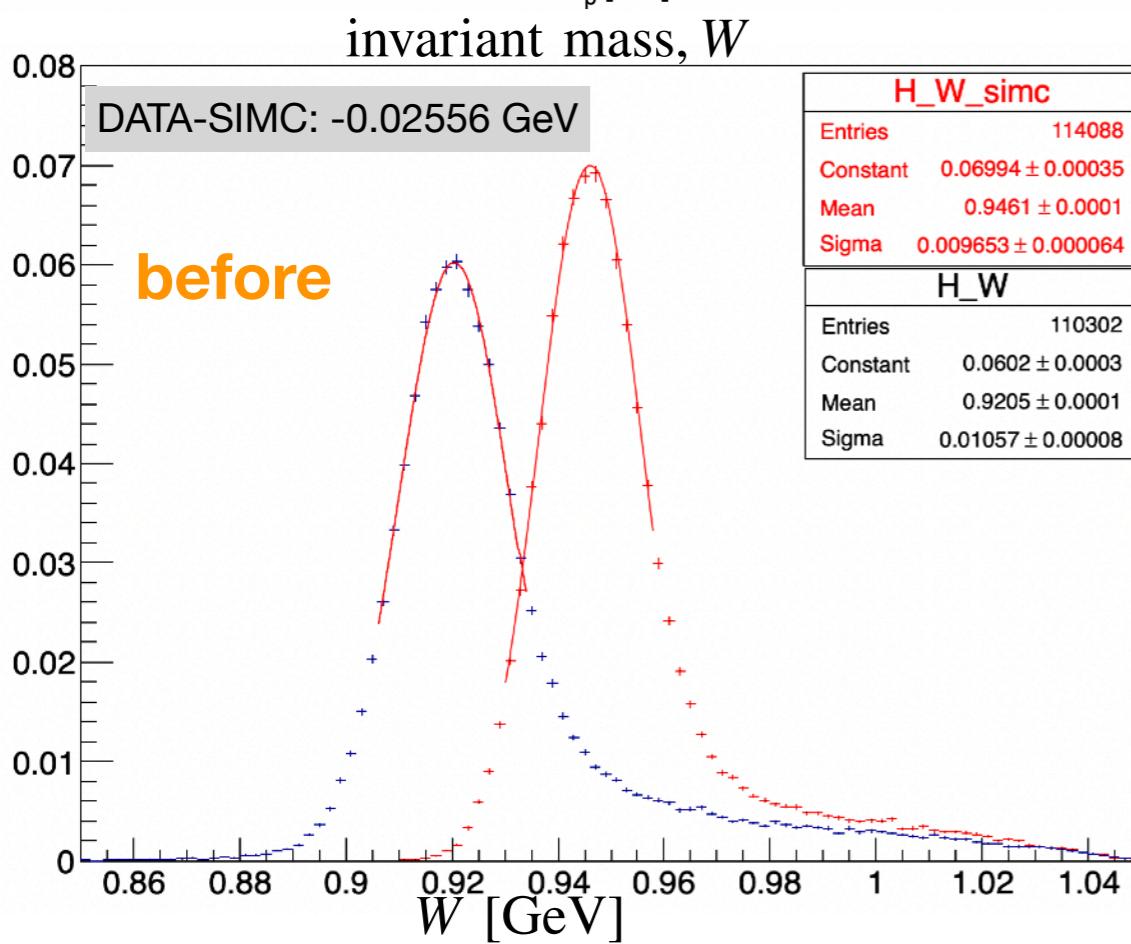
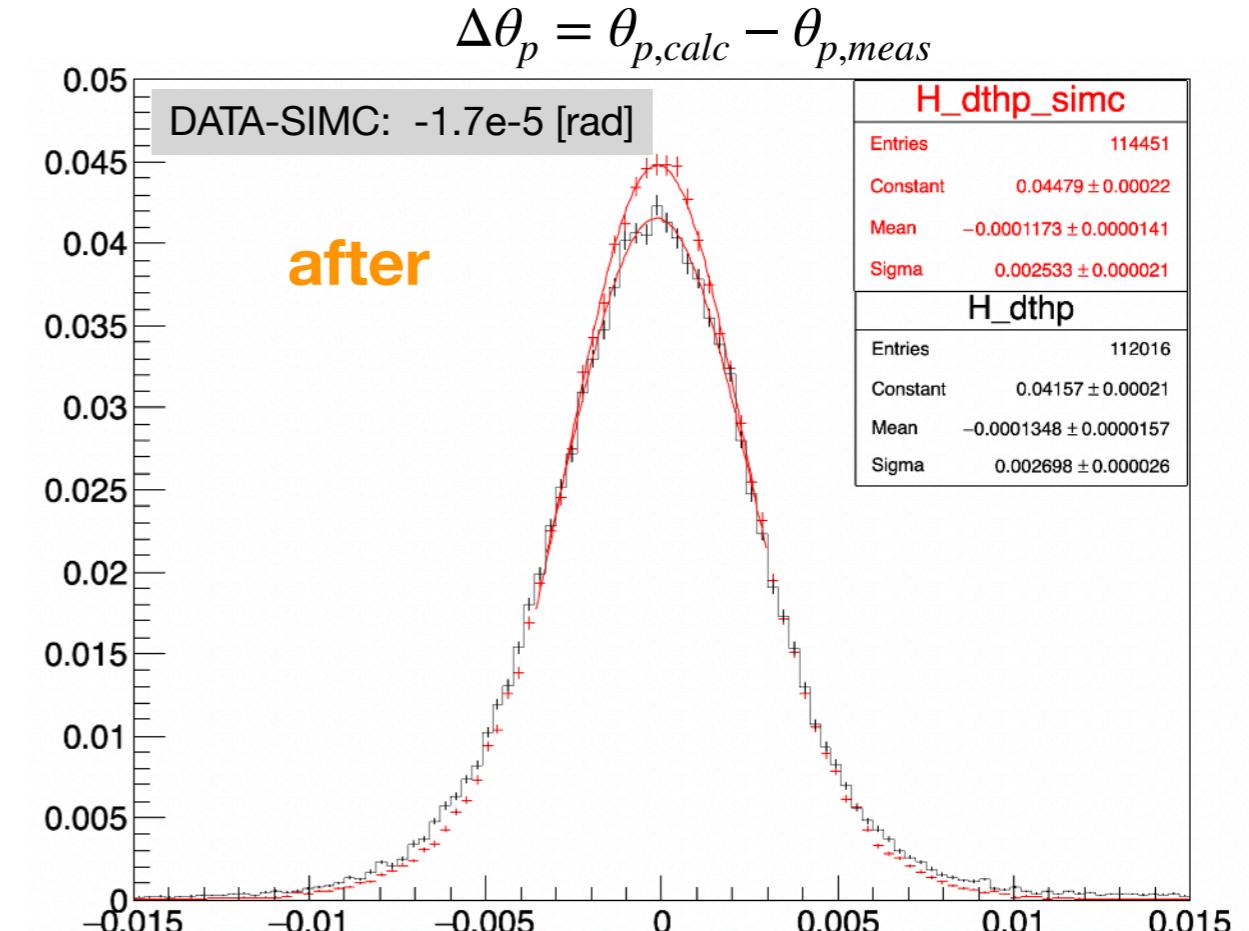
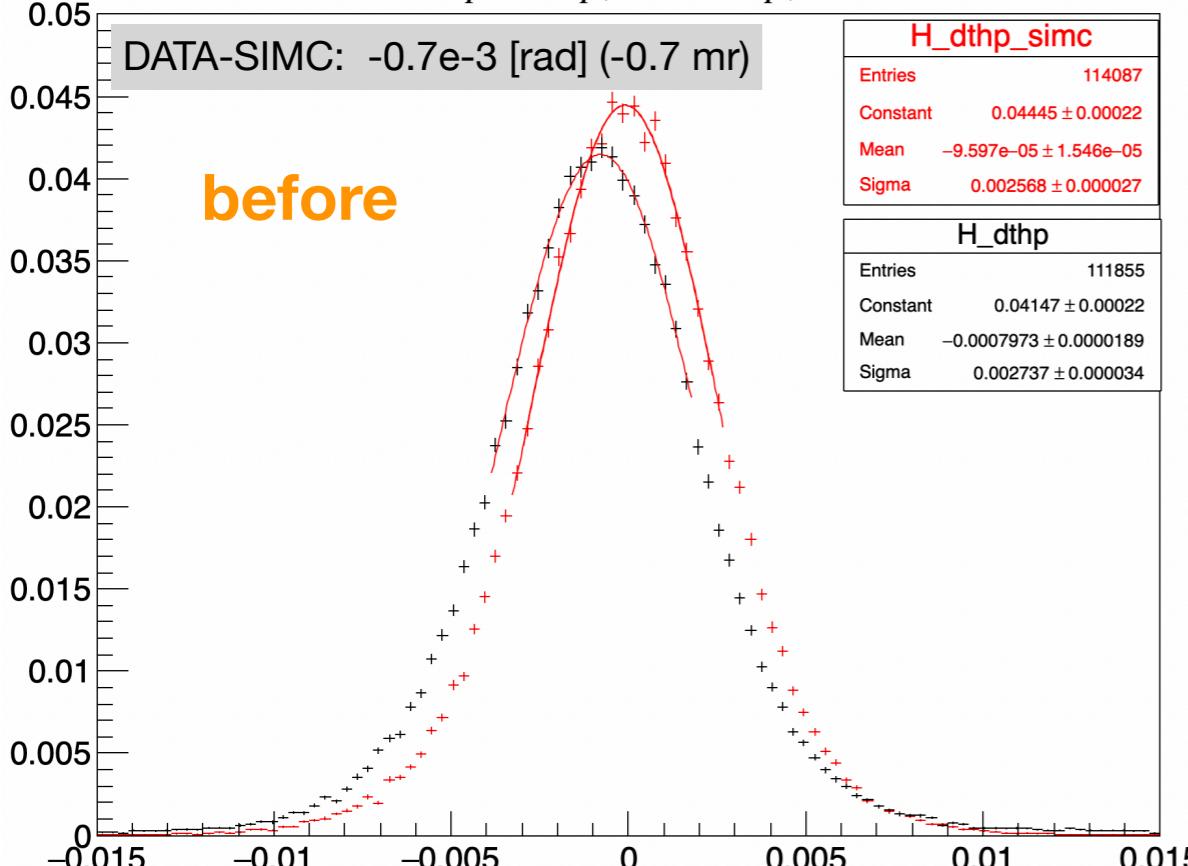
# Optimization Step 1 : determine (e-) angle offset as starting point

$$\Delta\theta_p = \theta_{p,calc} - \theta_{p,meas}$$

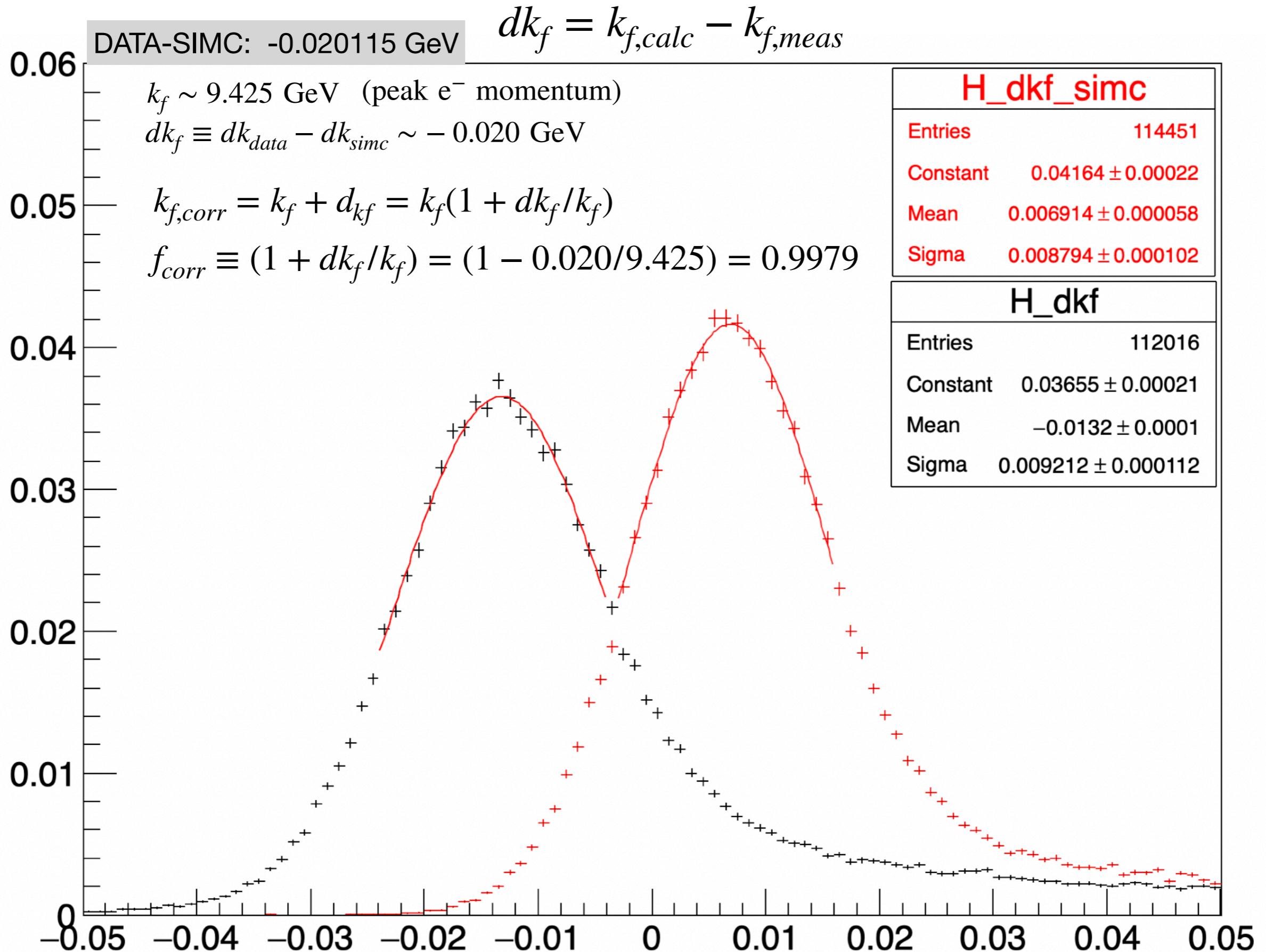


# Optimization Step 1 : applied (e-) angle offset to align proton angle

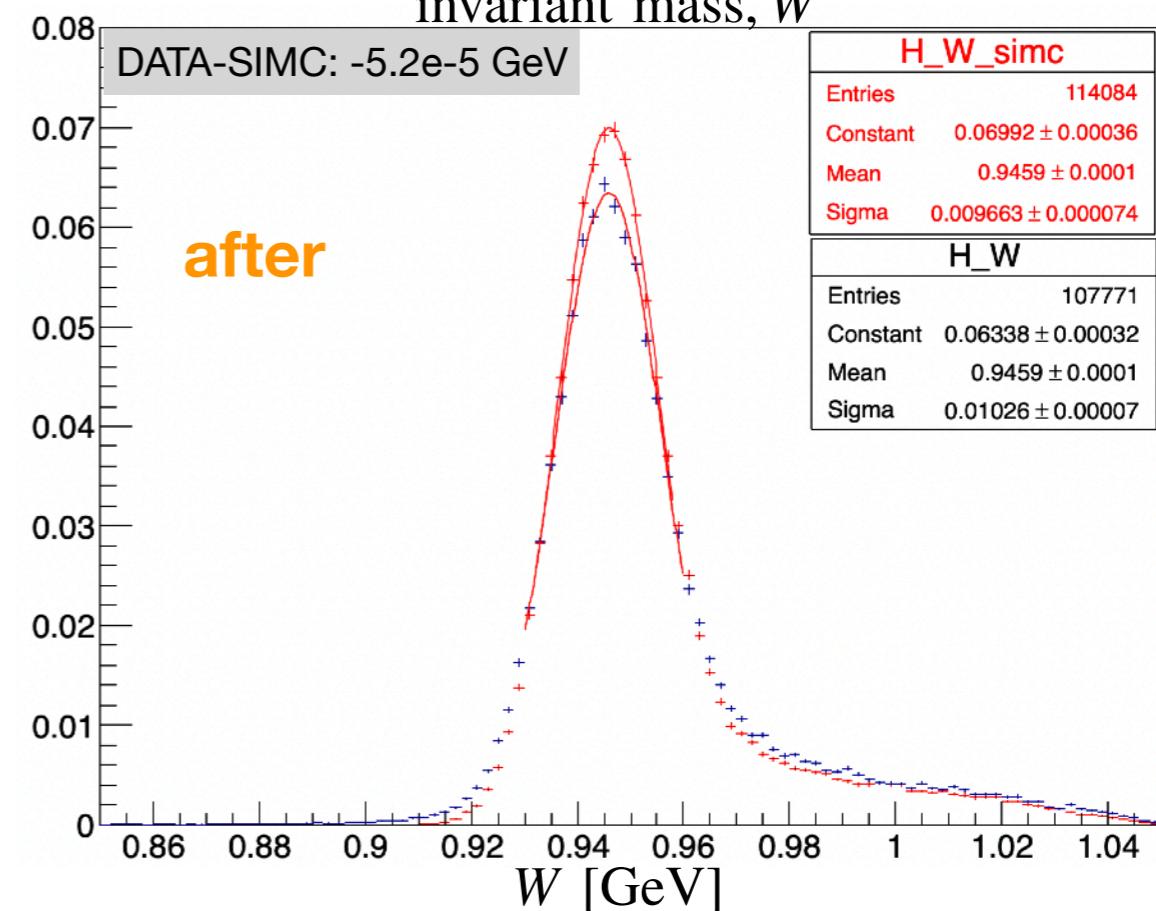
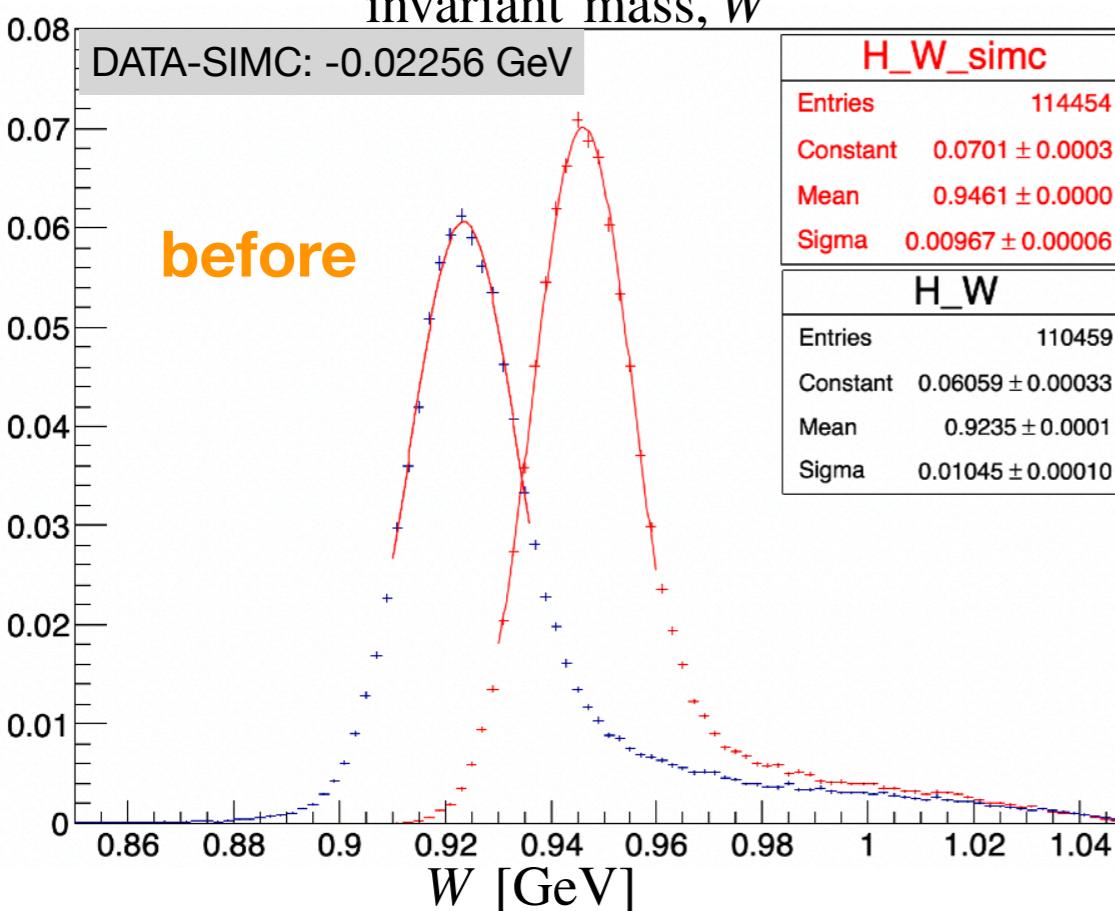
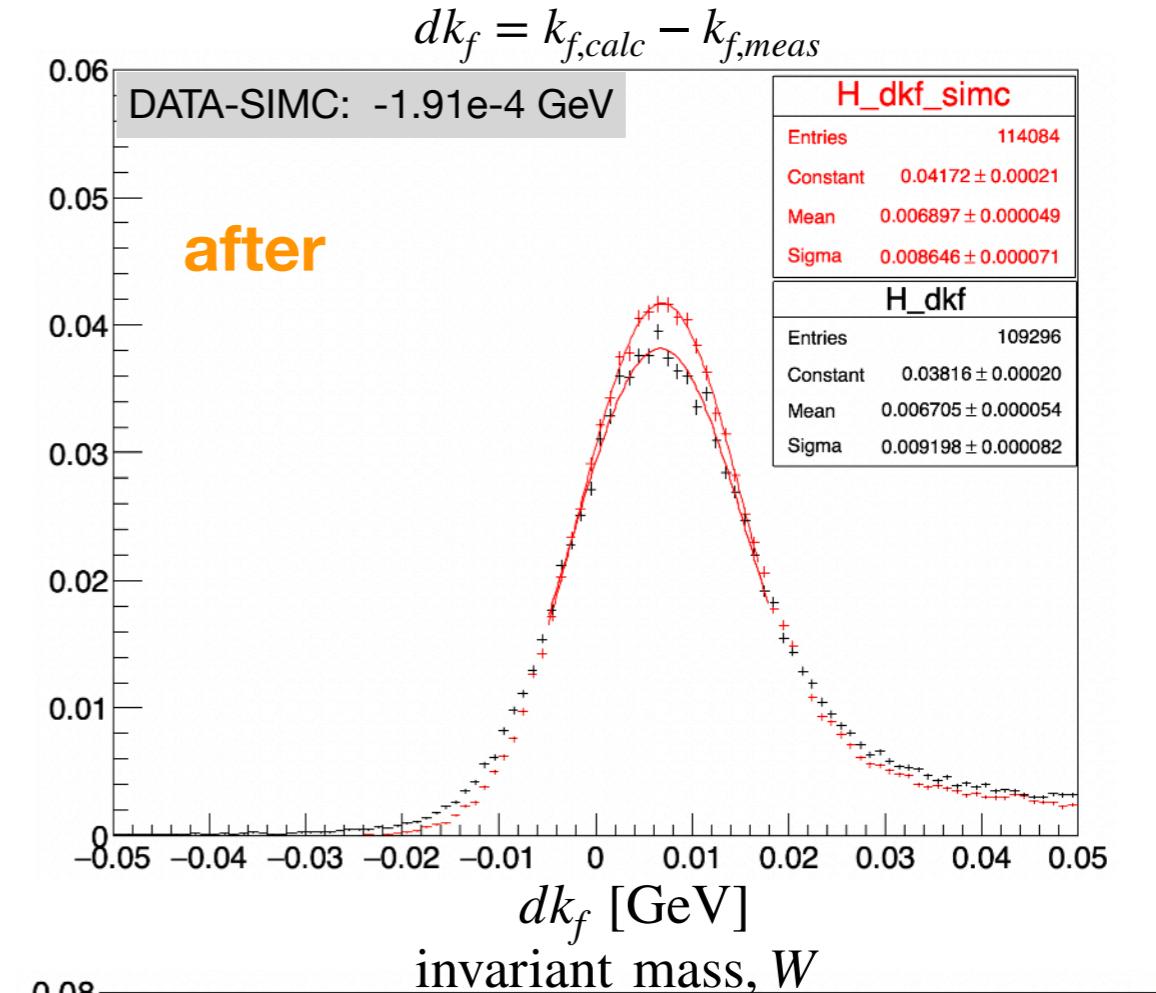
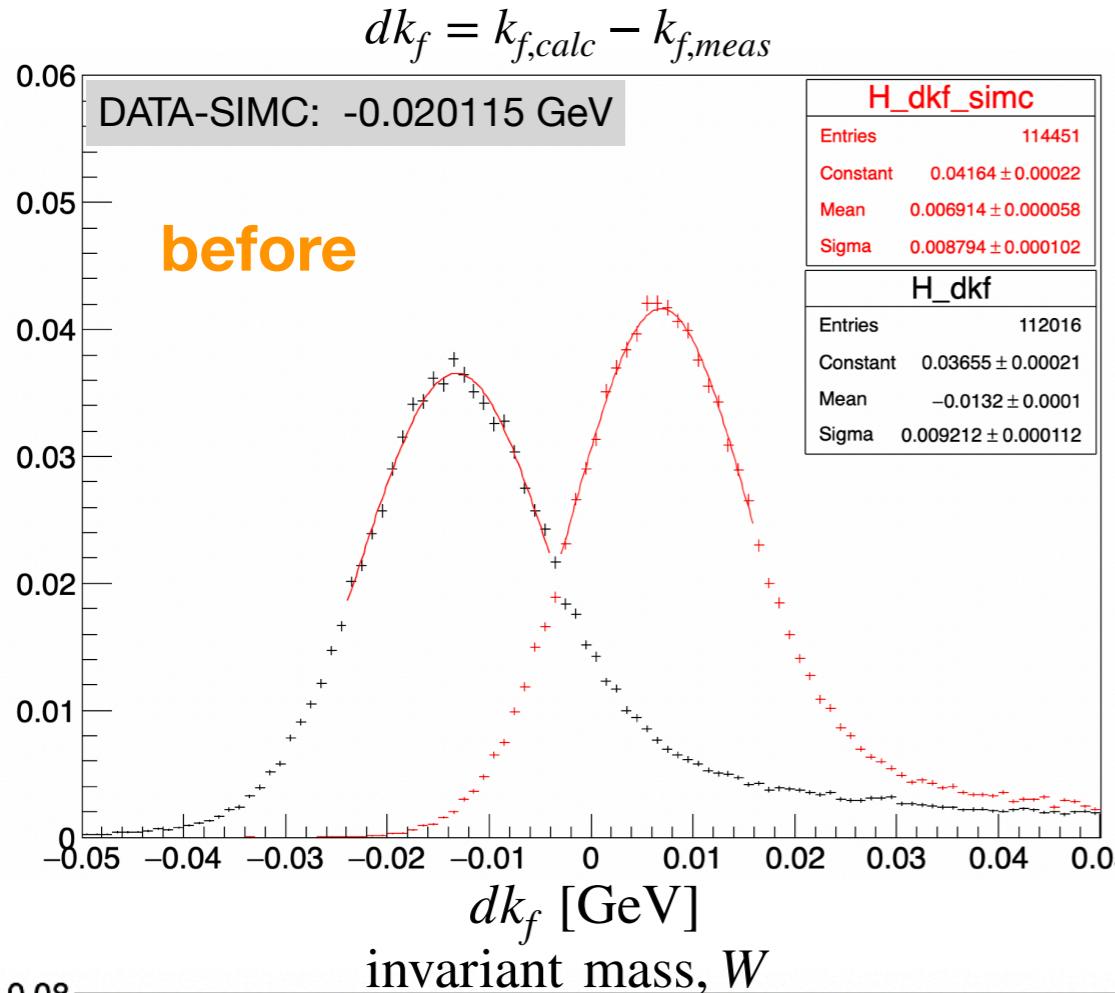
$$\Delta\theta_p = \theta_{p,calc} - \theta_{p,meas}$$



## Optimization Step 2 : determine SHMS (e-) momentum correction

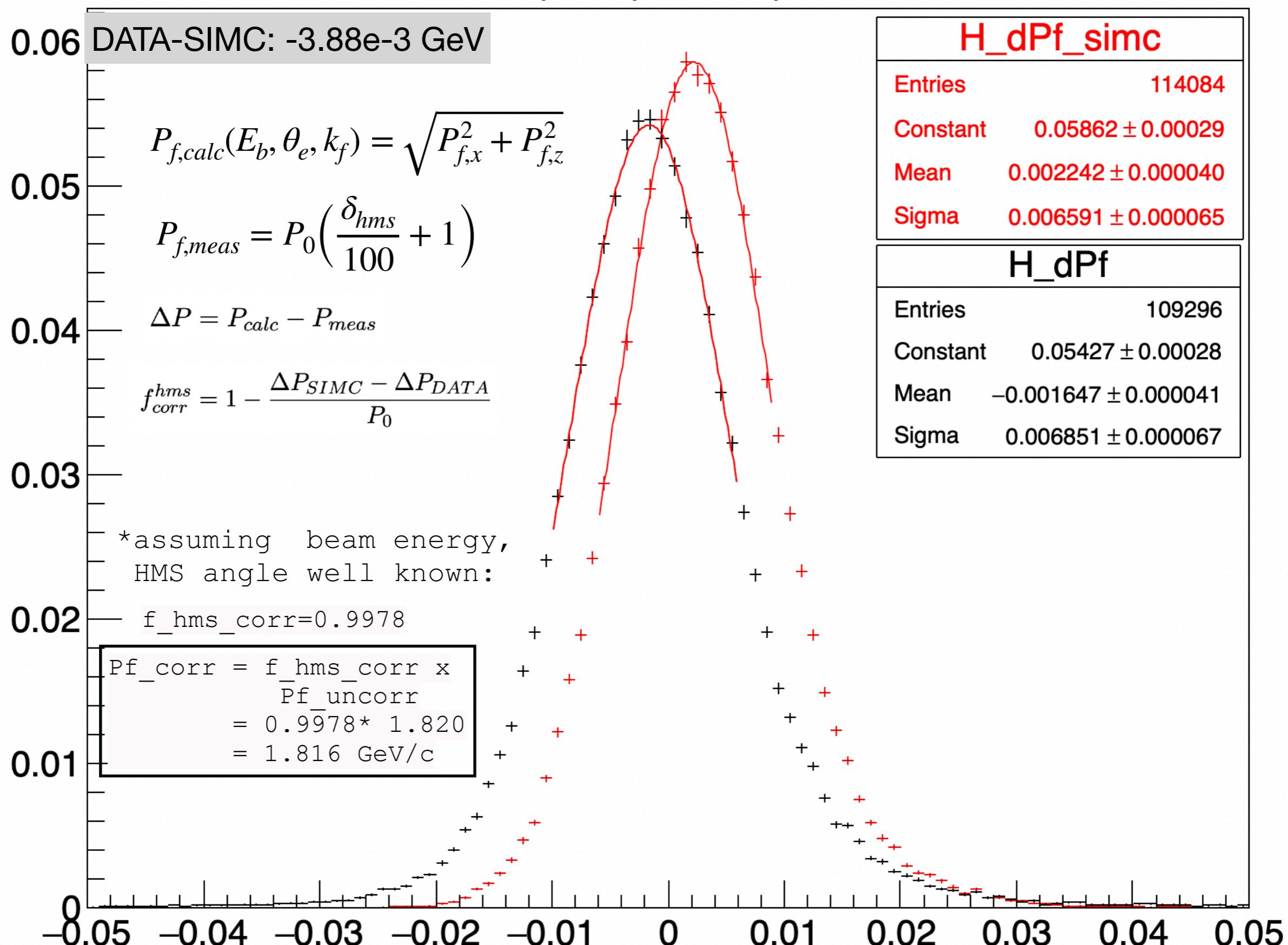


# Optimization Step 2 : applied SHMS (e-) momentum correction to align W



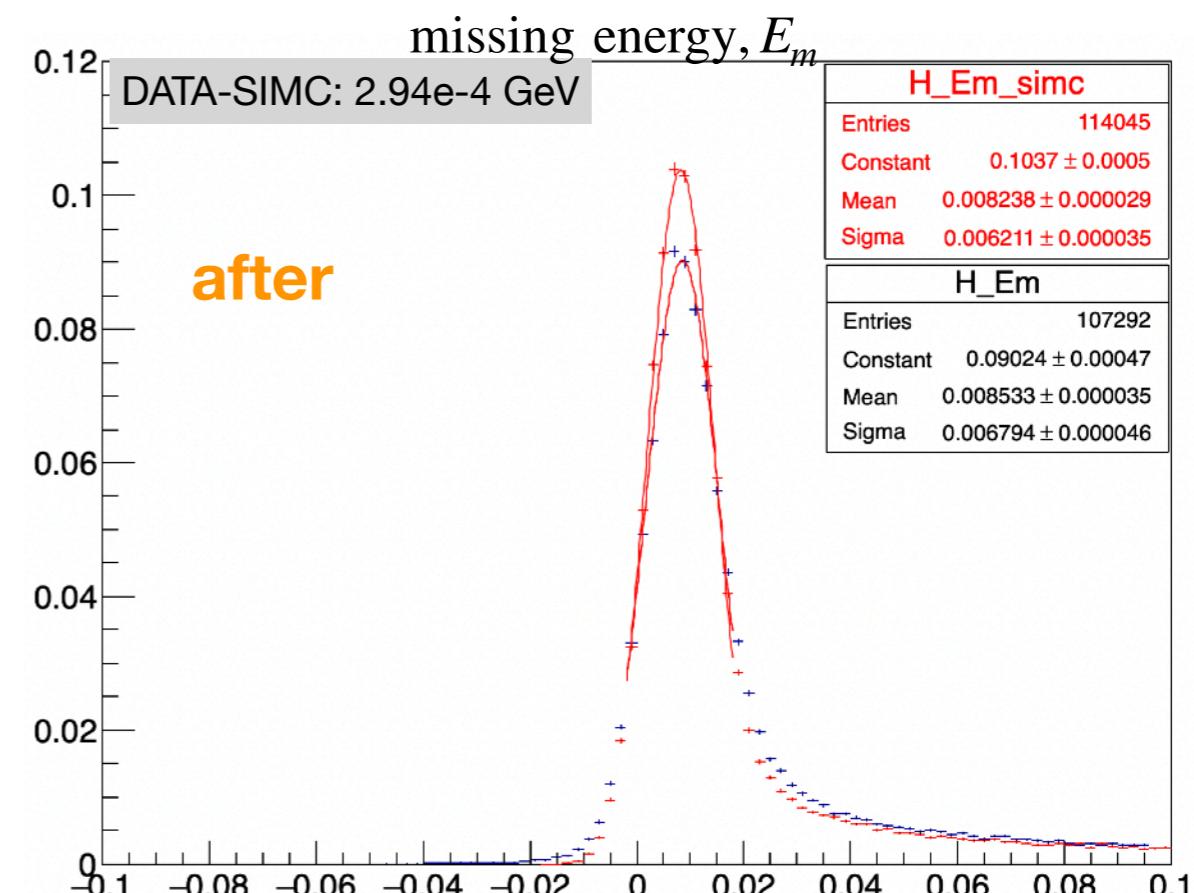
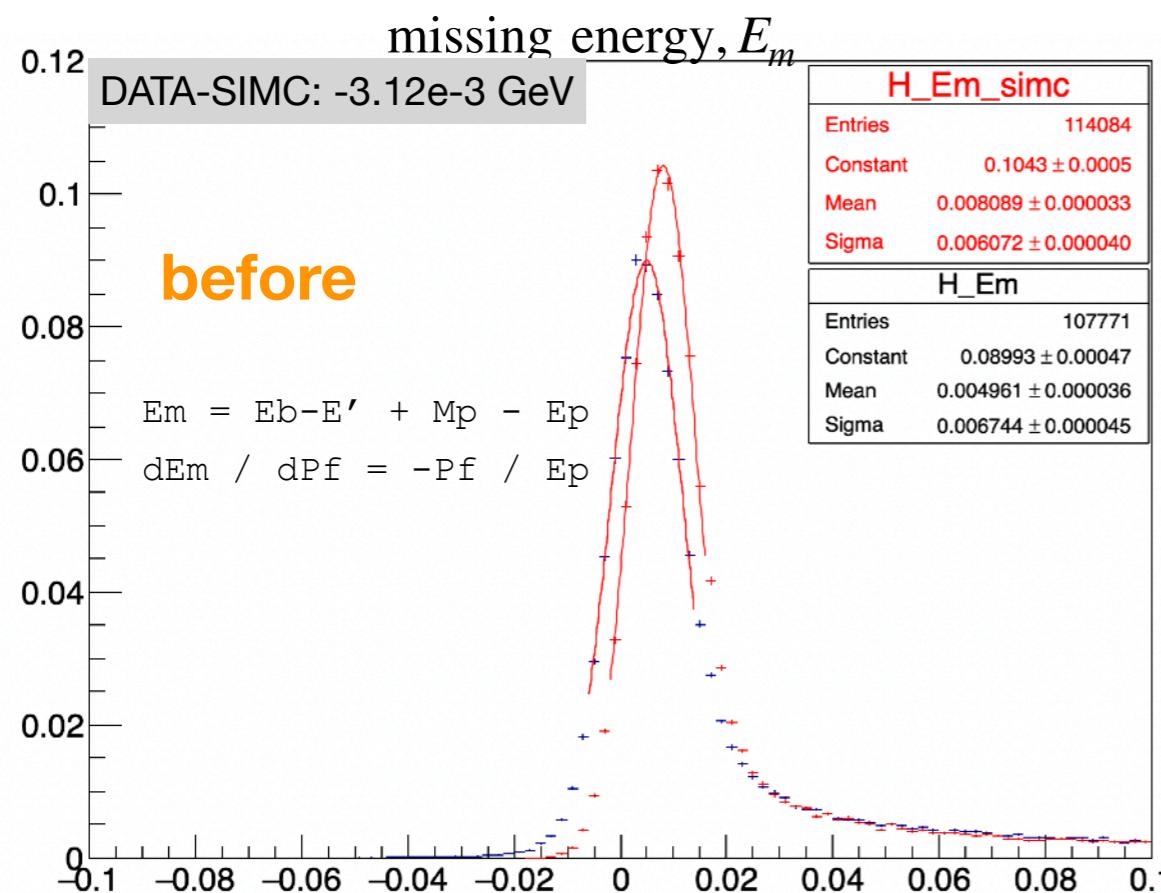
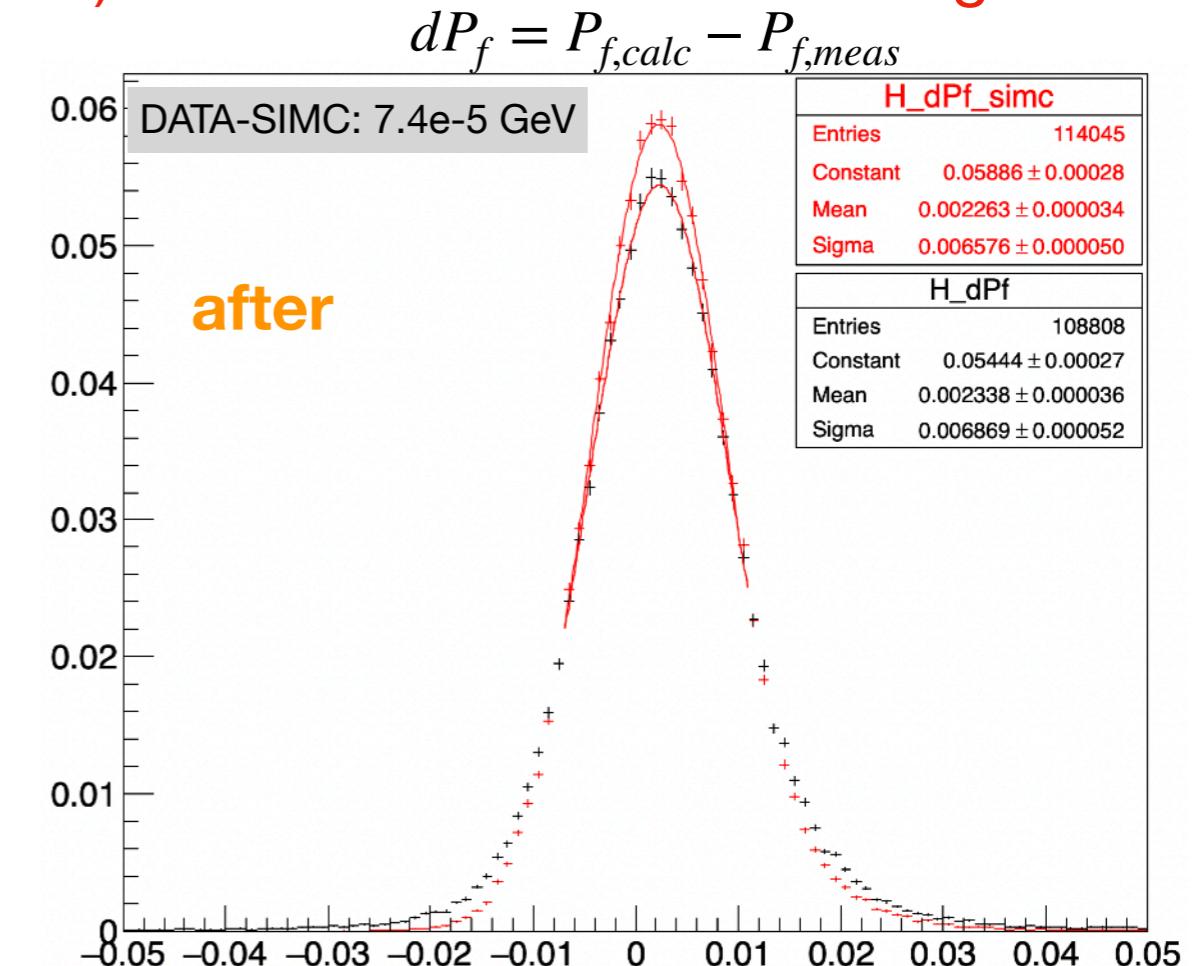
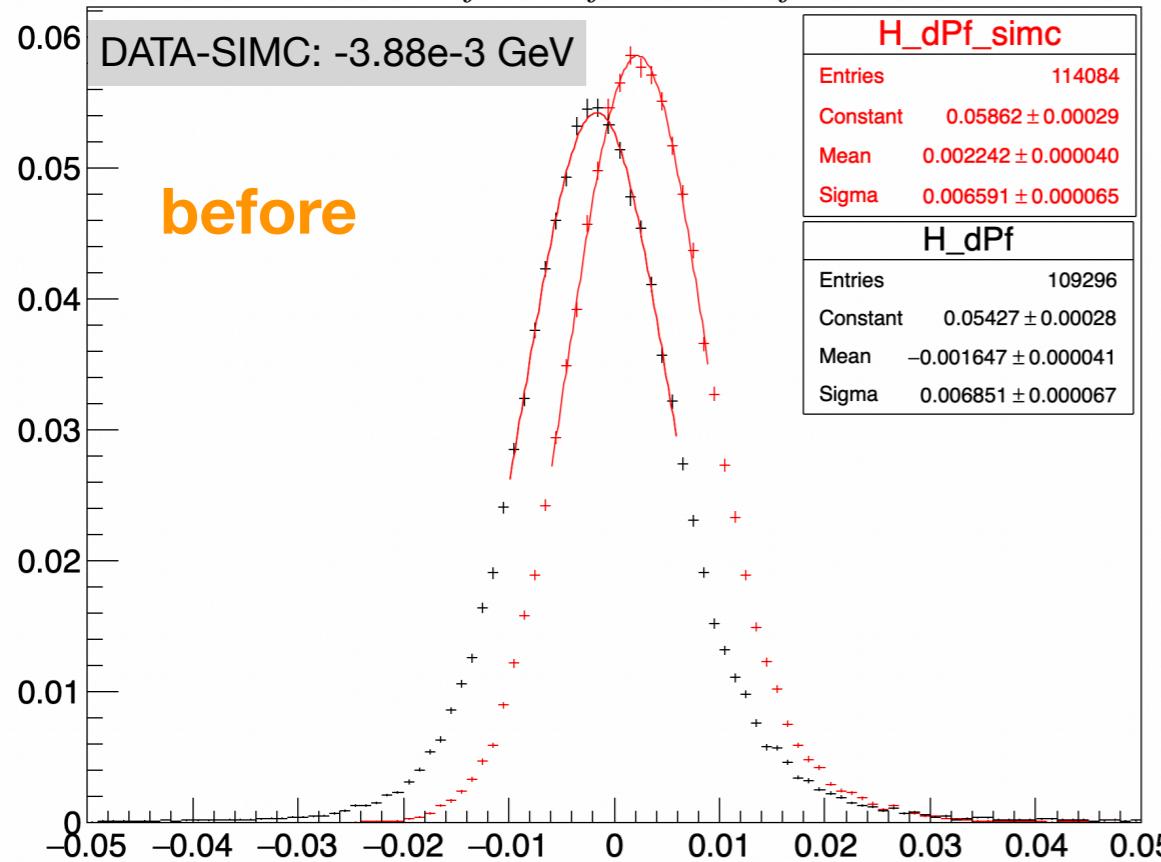
# Optimization Step 3 : determine HMS (proton) momentum correction

$$dP_f = P_{f,calc} - P_{f,meas}$$

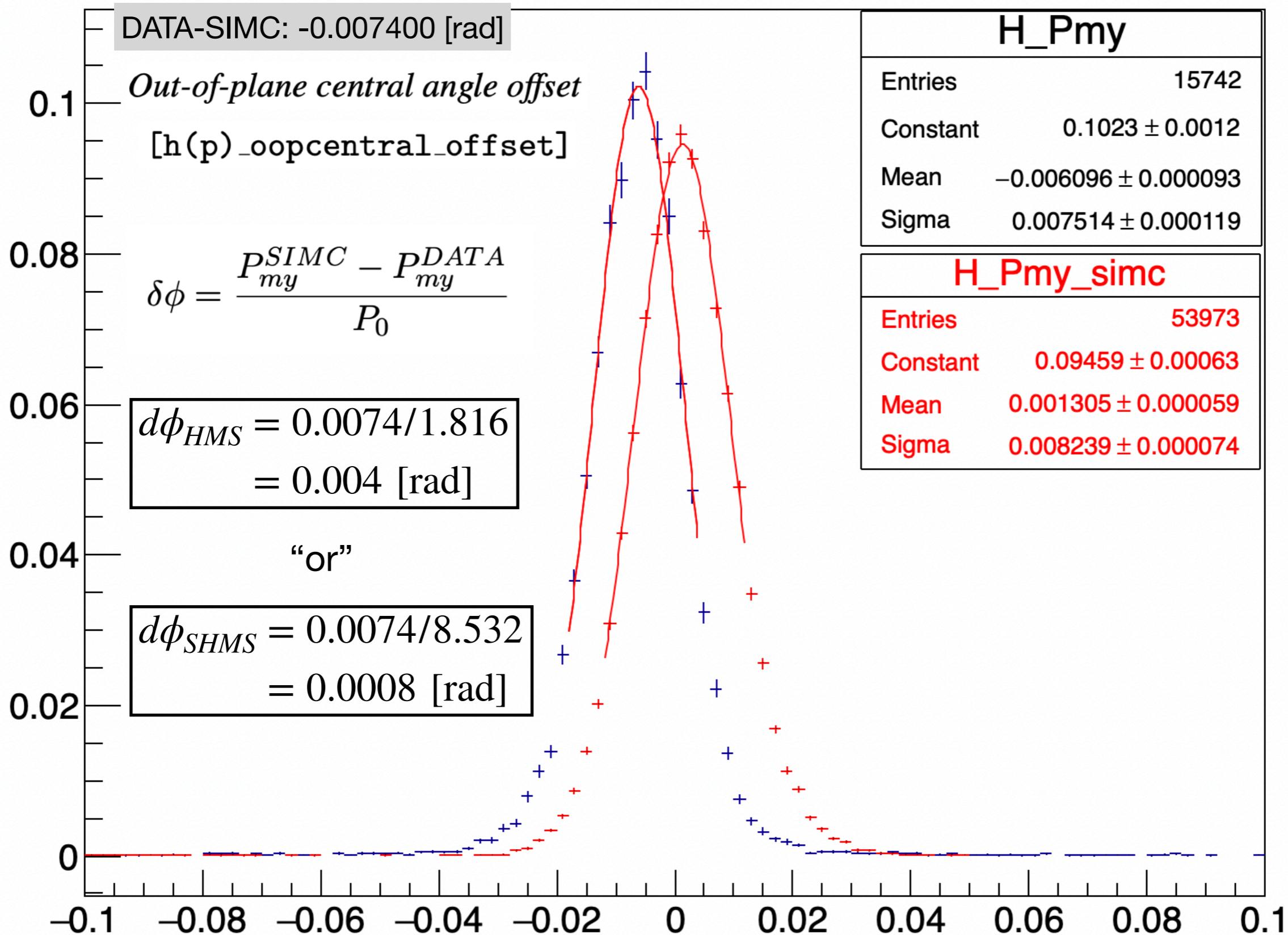


# Optimization Step 3 : applied HMS (proton) momentum correction to align Em

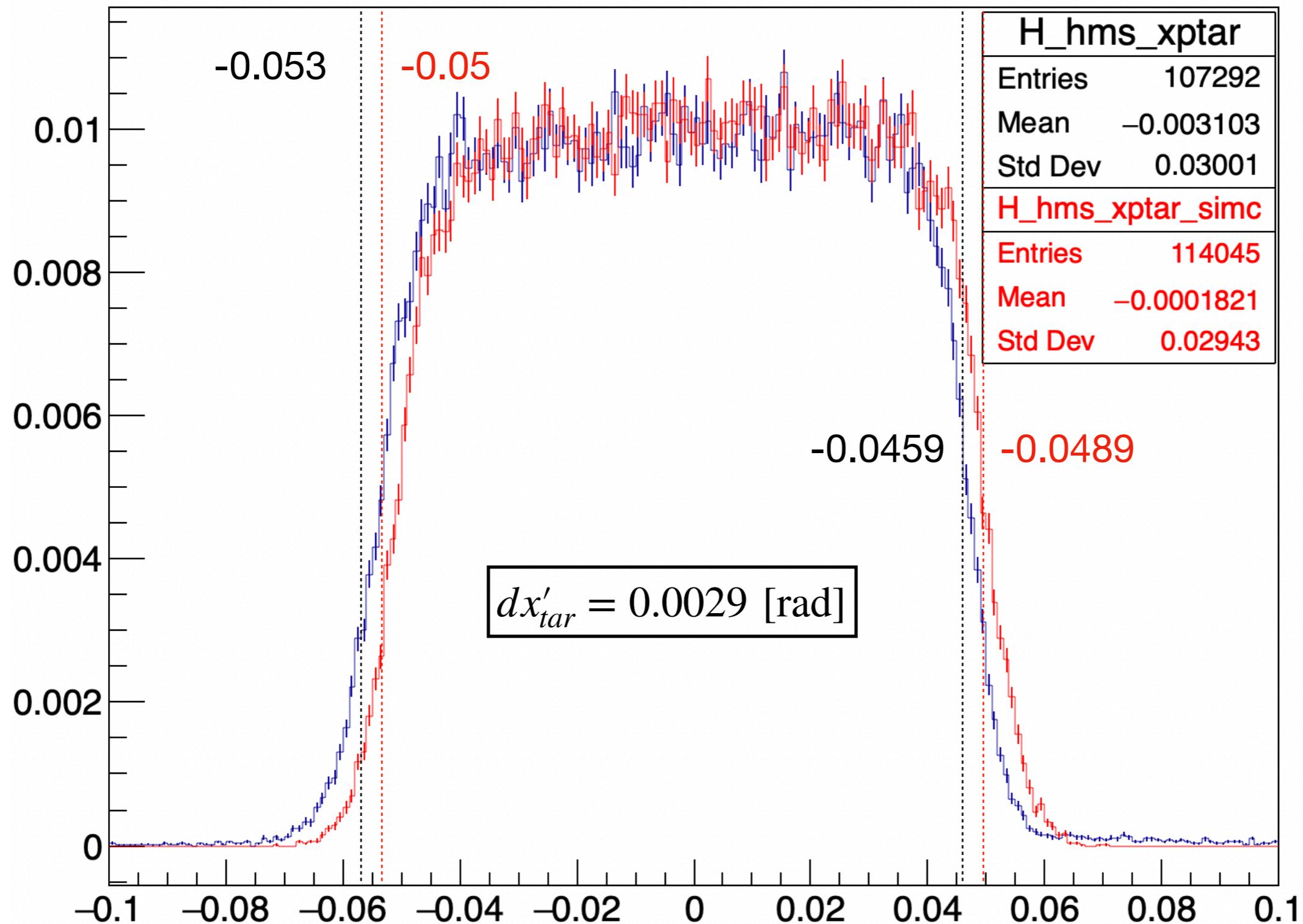
$$dP_f = P_{f,calc} - P_{f,meas}$$



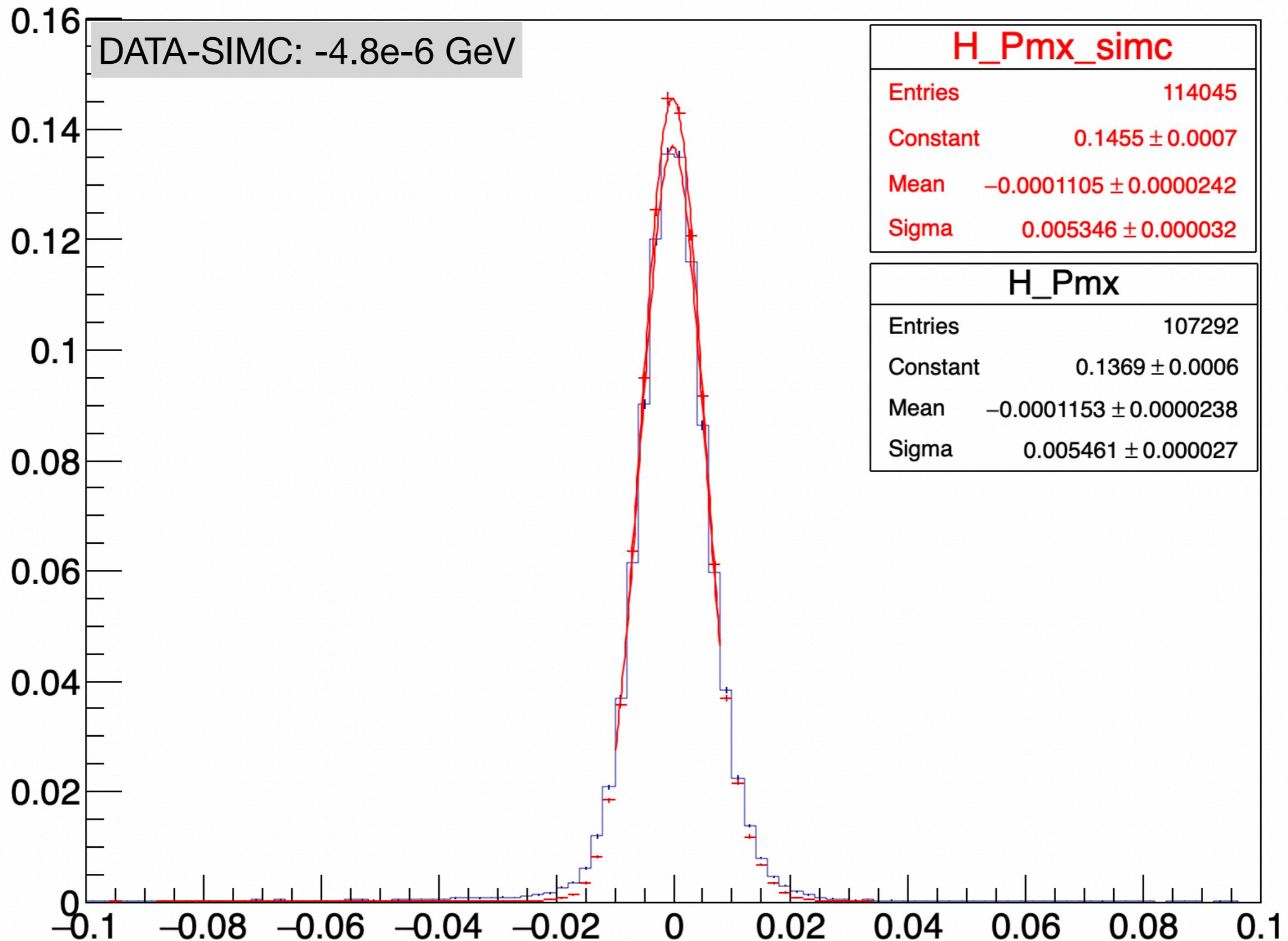
## Optimization Step 4 (part1) : determine out-of-plane central angle offsets for HMS( or SHMS) to align Missing Momentum Y (Lab)



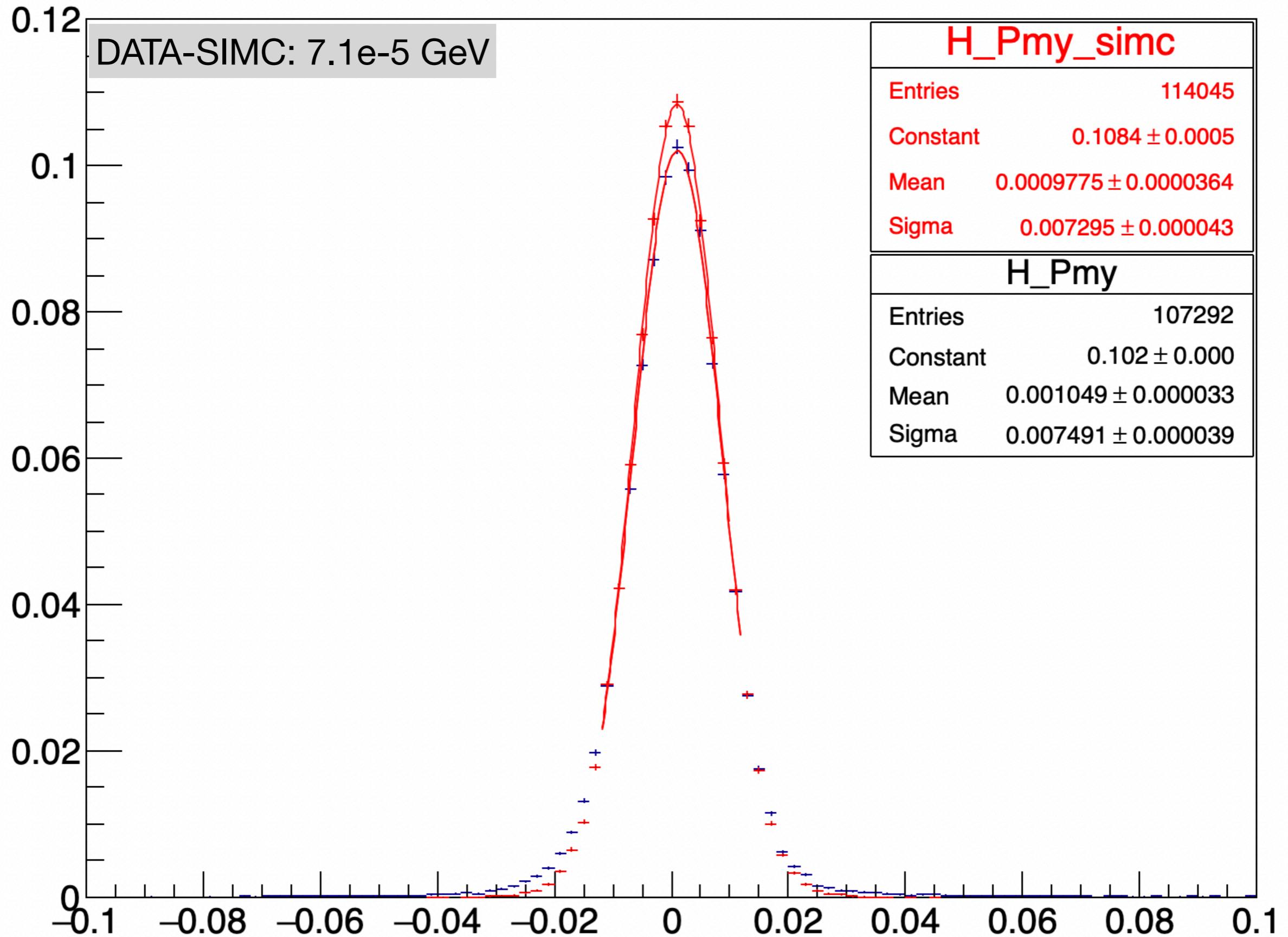
Optimization Step 4 (part2) : determine out-of-plane relative angle offsets for HMS to align X'tar



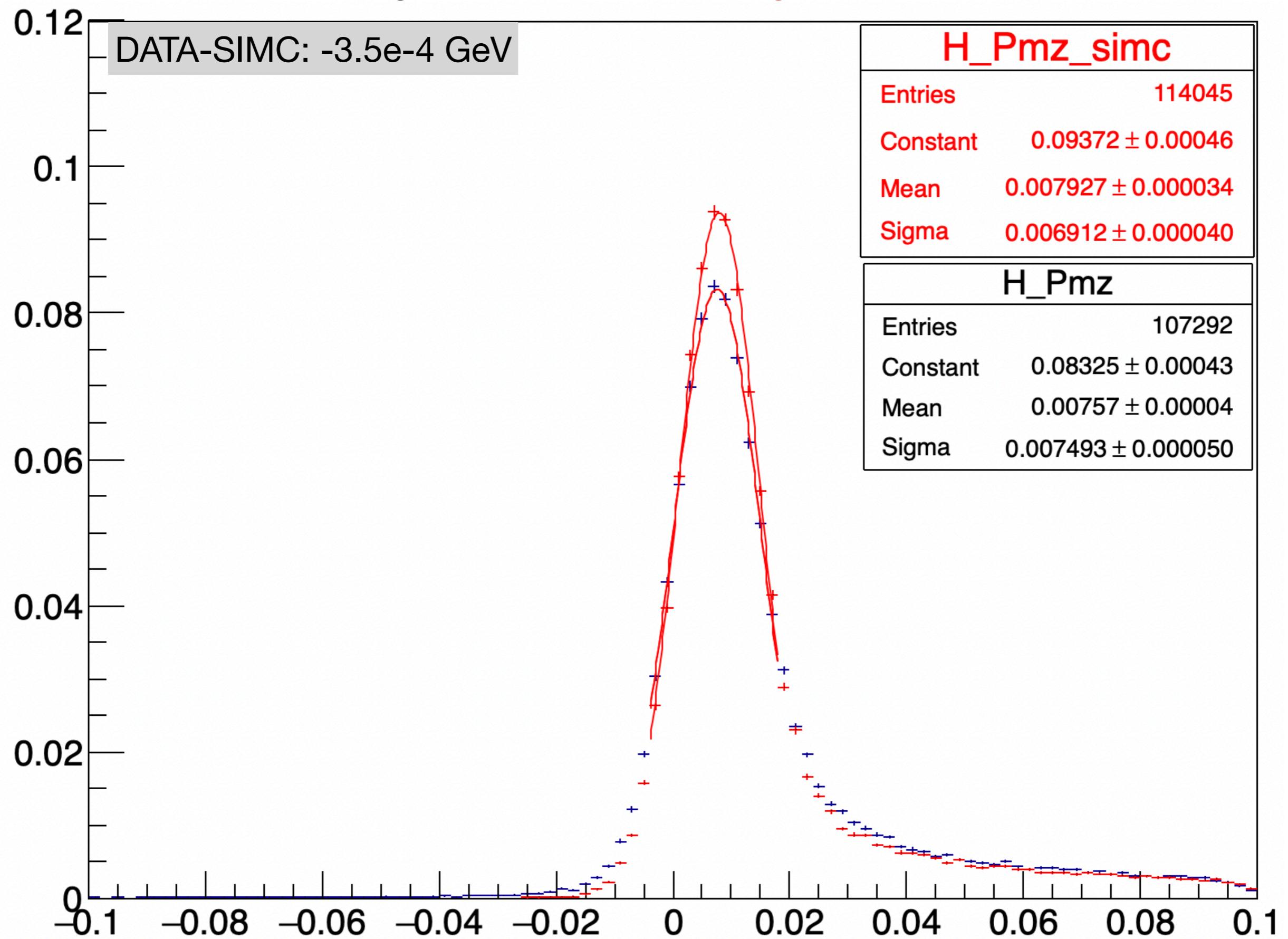
## Additional Alignment Checks : Missing Momentum X (Lab)



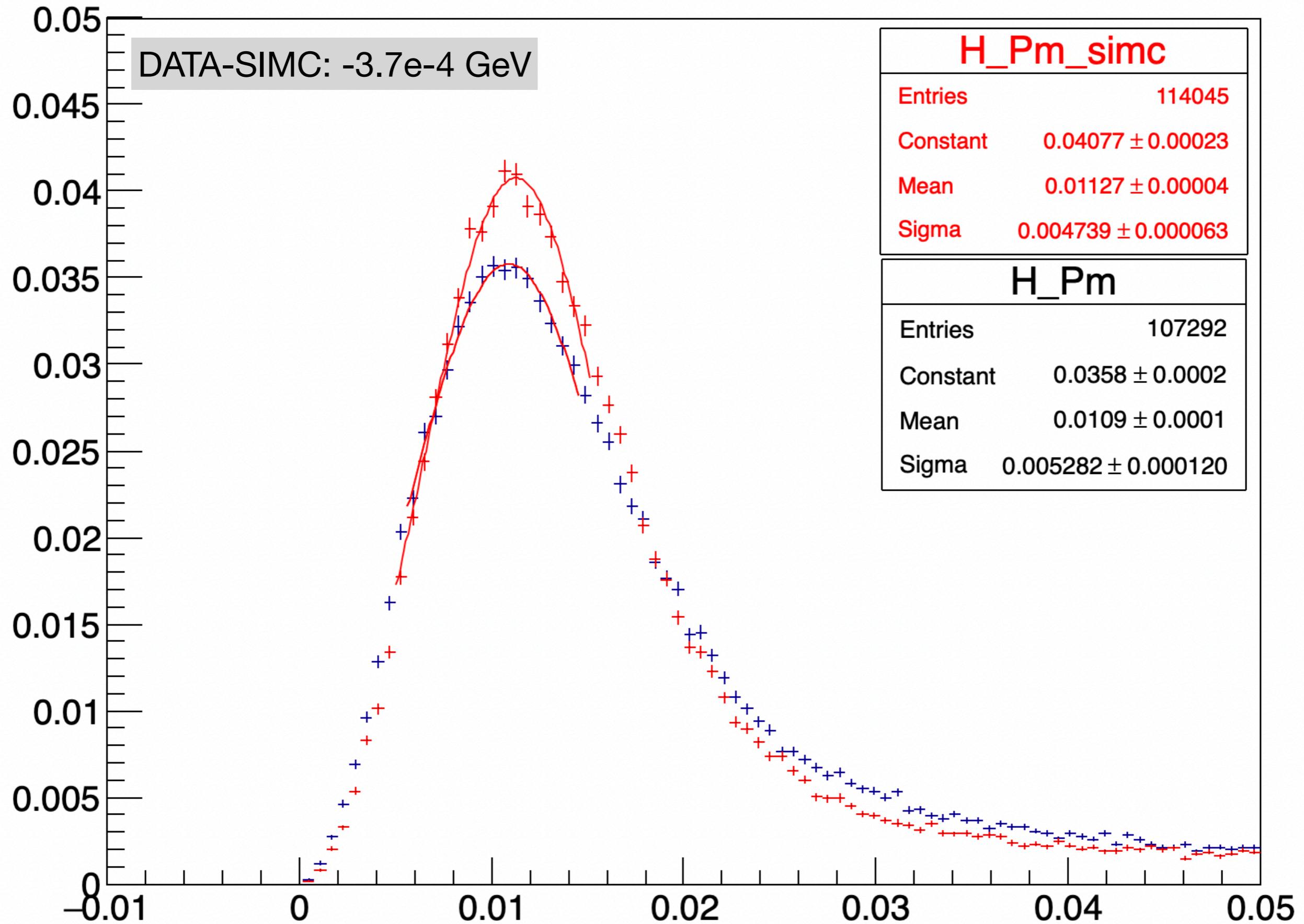
## Additional Alignment Checks : Missing Momentum Y (Lab)



## Additional Alignment Checks : Missing Momentum Z (Lab)



## Additional Alignment Checks : Missing Momentum



Nomenclature: Eb -> Beam Energy

E' -> Electron Momentum

th\_e -> Electron Angle

Mp -> Proton Mass

nu -> Energy Transfer (Eb - E')

Q2 -> 4-Momentum Transfer

Formulas:  $W(Eb, E', \text{th}_e) = Mp^{**2} + 2*Mp*nu - Q2$  (Invariant Mass)

$$nu = Eb - E'$$

$$Q2 = 4*Eb*E'*\sin^2(\text{th}_e / 2)$$

Derivatives:  $dW / dEb = E' / Eb$

$$dW / dE' = - Eb / E'$$

$$dW / d\text{th}_e = - 2 * Eb * E' * \sin(\text{th}_e/2) * \cos(\text{th}_e/2) / Mp$$

## Missing Energy, Derivatives

$$\text{Formula: } E_m(E_b, E', P_f) = \nu + M_p - E_p$$

$$\nu = E_b - E'$$

$$E_p = \sqrt{M_p^2 + P_f^2}$$

Nomenclature:  $E_b \rightarrow$  Beam Energy

$E' \rightarrow$  Electron Momentum

$M_p \rightarrow$  Proton mass

$E_p \rightarrow$  Proton final energy

$P_f \rightarrow$  Proton final momentum

$\nu \rightarrow (E_b - E')$  energy transfer

$$\text{Derivatives: } \frac{dE_m}{dE_b} = 1$$

$$\frac{dE_m}{dE'} = -1$$

$$\frac{dE_m}{dP_f} = -P_f / E_p$$