DDVCS

universite PARIS-SACLAY

École Doctorale PHENIICS Doctoral School

BY:

Sebastian Alvarado

Belitsky, Andrei V., and Dieter Mueller.
Phys. Rev. D 68.11 (2003): 116005.

of the first interference term. In case when only the lepton beam of a specified single charge is available, on can form asymmetries with an odd weight

$$w^{\rm odd}(\phi_\ell,\theta_\ell) \qquad (167)$$
$$= \{\cos\theta_\ell,\ \cos\varphi_\ell,\ \cos(2\varphi_\ell)\cos\theta_\ell,\ \cos(3\varphi_\ell),\ \sin\varphi_\ell,\ \sin(2\varphi_\ell)\cos\theta_\ell,\ \sin(3\varphi_\ell),\ \dots\},$$

so that the squared amplitudes exactly drop out

$$\int d\Omega_\ell\, w^{\rm odd}(\phi_\ell,\theta_\ell)\frac{d\sigma}{d\Omega_\ell} \propto \int d\Omega_\ell\, w^{\rm odd}(\phi_\ell,\theta_\ell)\left\{\pm\mathcal{T}^*_{\rm BH_1}\mathcal{T}_{\rm BH_2} + \Re{\rm e}\left(\mathcal{T}^*_{\rm BH_2}\mathcal{T}_{\rm VCS}\right)\right\}. \qquad (168)$$

After the subtraction of the remaining BH interference is done, one measures the leading twist-two Fourier coefficients. Still, this procedure may allow a handle on the real part of the Compton form factors. If both kinds of the lepton-beam charges are available, the BH contribution drops in the charge even combination

$$\int d\Omega_\ell\, w^{\rm odd}(\phi_\ell,\theta_\ell)\frac{d\sigma^+ + d\sigma^-}{d\Omega_\ell} \propto \int d\Omega_\ell\, w^{\rm odd}(\phi_\ell,\theta_\ell)\,\Re{\rm e}\left(\mathcal{T}^*_{\rm BH_2}\mathcal{T}_{\rm VCS}\right). \qquad (169)$$

To illustrate the feasibility of the subtraction procedure, we consider the charge and the angular asymmetries

$$\left\{\begin{matrix} A^{\cos\varphi_\ell}_{\rm CA} \\ A^{\cos\varphi_\ell} \end{matrix}\right\} = \frac{1}{\mathcal{N}}\int_{\pi/4}^{3\pi/4} d\theta_\ell \int_0^{2\pi} d\phi \int_0^{2\pi} d\varphi_\ell\, 2\cos\varphi_\ell \left\{\begin{matrix} \left(d\sigma^+ + d\sigma^-\right)/2d\Omega_\ell d\phi \\ d\sigma^-/d\Omega_\ell d\phi \end{matrix}\right\}, \qquad (170)$$

performed with respect to $2\cos\varphi_\ell$, where in both cases we choose the normalization to be

$$\mathcal{N} = \int_{\pi/4}^{3\pi/4} d\theta_\ell \int_0^{2\pi} d\phi \int_0^{2\pi} d\varphi_\ell \frac{d\sigma^-}{d\Omega_\ell d\phi}.$$

$${\rm c}c^2_{10} \propto \Re{\rm e}\left\{\frac{\xi}{\eta}F_1\mathcal{H} - \frac{\xi}{\eta}\frac{\Delta^2}{4M_N^2}F_2\mathcal{E} + \eta\left(F_1 + F_2\right)\widetilde{\mathcal{H}}\right\},$$

Following the results from Belitsky-Muller.
A cosine moment of the DDVCS cross-section access the real part of CFF.

In particular:

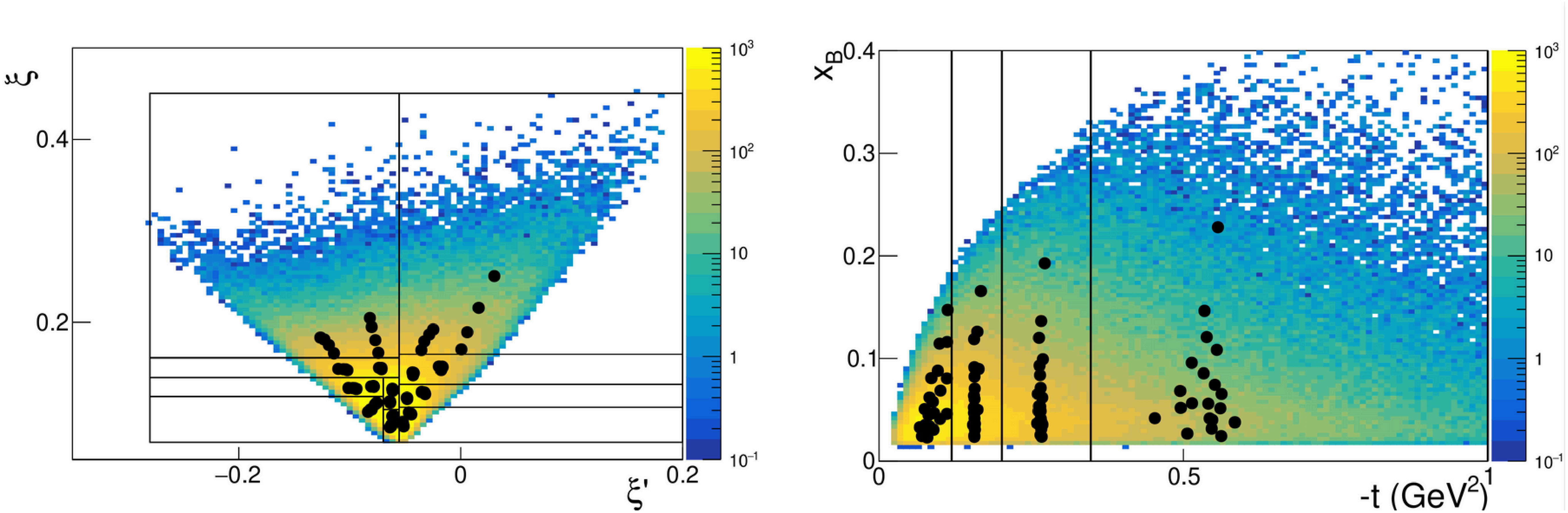
- It access the same CFF combination of a Charge Asymmetry
- Depends only on the BH1*BH2 and VCS*BH2 terms
- As the BH can be computed, we might extract the VCS*BH2 term

In the following, I will describe the workflow through cosine moment extraction

Simulation workflow

For the statistical error:

1. I generated VCS + BH events I generated with EpIC
2. These events were passed to the uCLAS detector through OSG.
3. I re-scaled the events according to the cross-section and luminosity (1e37 * 200* 3600 * 24 * generator_xsec / N_events)



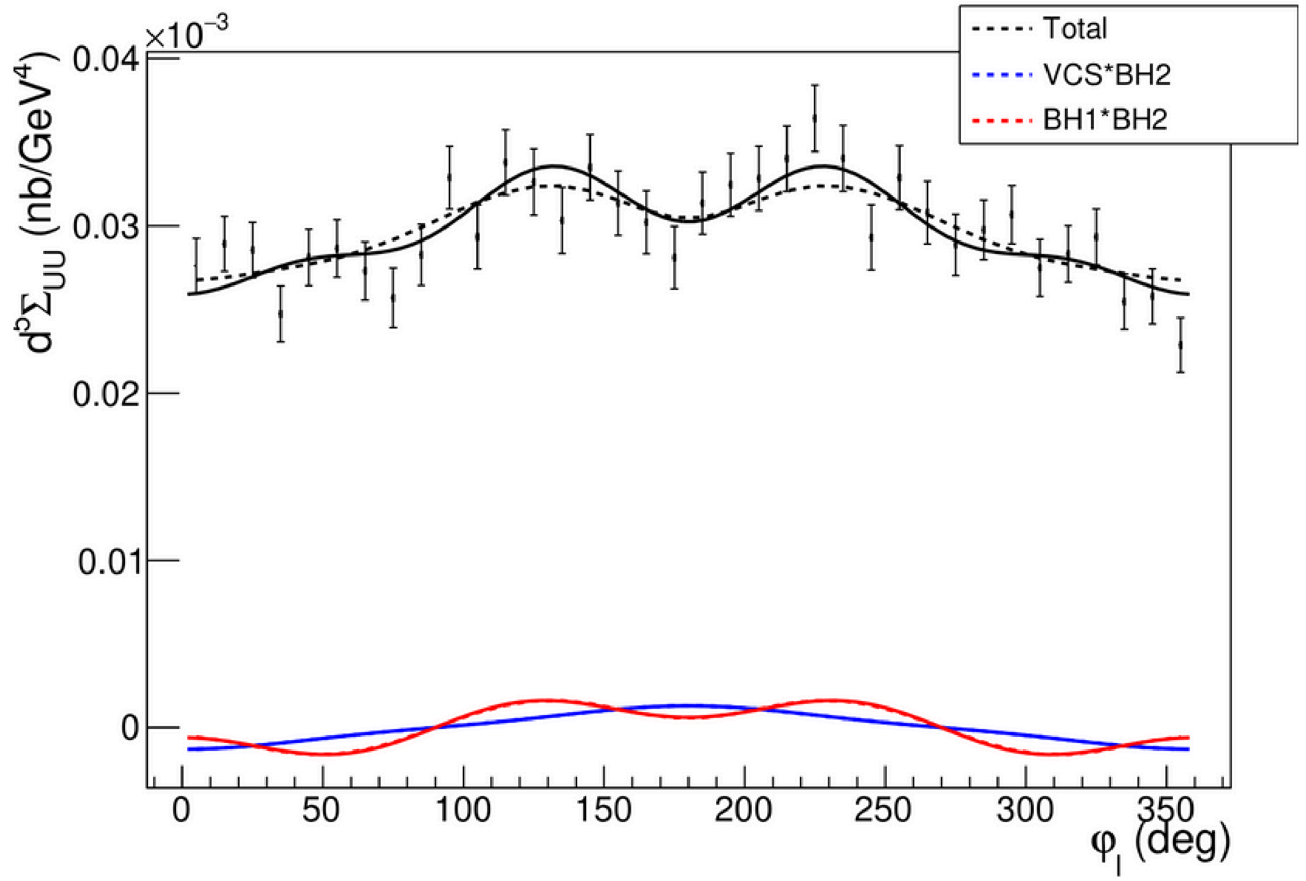
Using the expected number of events in the explored phase space I built

- 10 bins in (ξ',ξ)
- 4 bins in t
- 2 bins in Q^2

80 bins in total

Generation of pseudo-data

1. Pseudo data is generated at the total DDVCS + BH cross-section value
   a. 36 evenly distributed points i.e. φ ranges of 10°
2. Data points are given a statistical error bar given the realistic simulation:
3. Pseudo-data is randomly distributed following Gaussian distribution $\sigma \rightarrow \mathcal{G}auss(\sigma, \Delta\sigma)$
   a. Mean at the nominal value
   b. Sigma equal to the statistical error bar
4. Pseudo-data is fitted to $\sigma = a + b\cos(\phi) + c\cos(2\phi) + d\cos(3\phi) + e\cos(4\phi)$
   a. cosφ moment is given by the 'b' parameter
5. Store 'b' parameter for posprocessing
6. The above steps are repeated 10K times



With this study we aim to determine if:

- There is a bias in the extracted VCS*BH2 cos moment
- The variance from the fit approach allows precise enough measurements

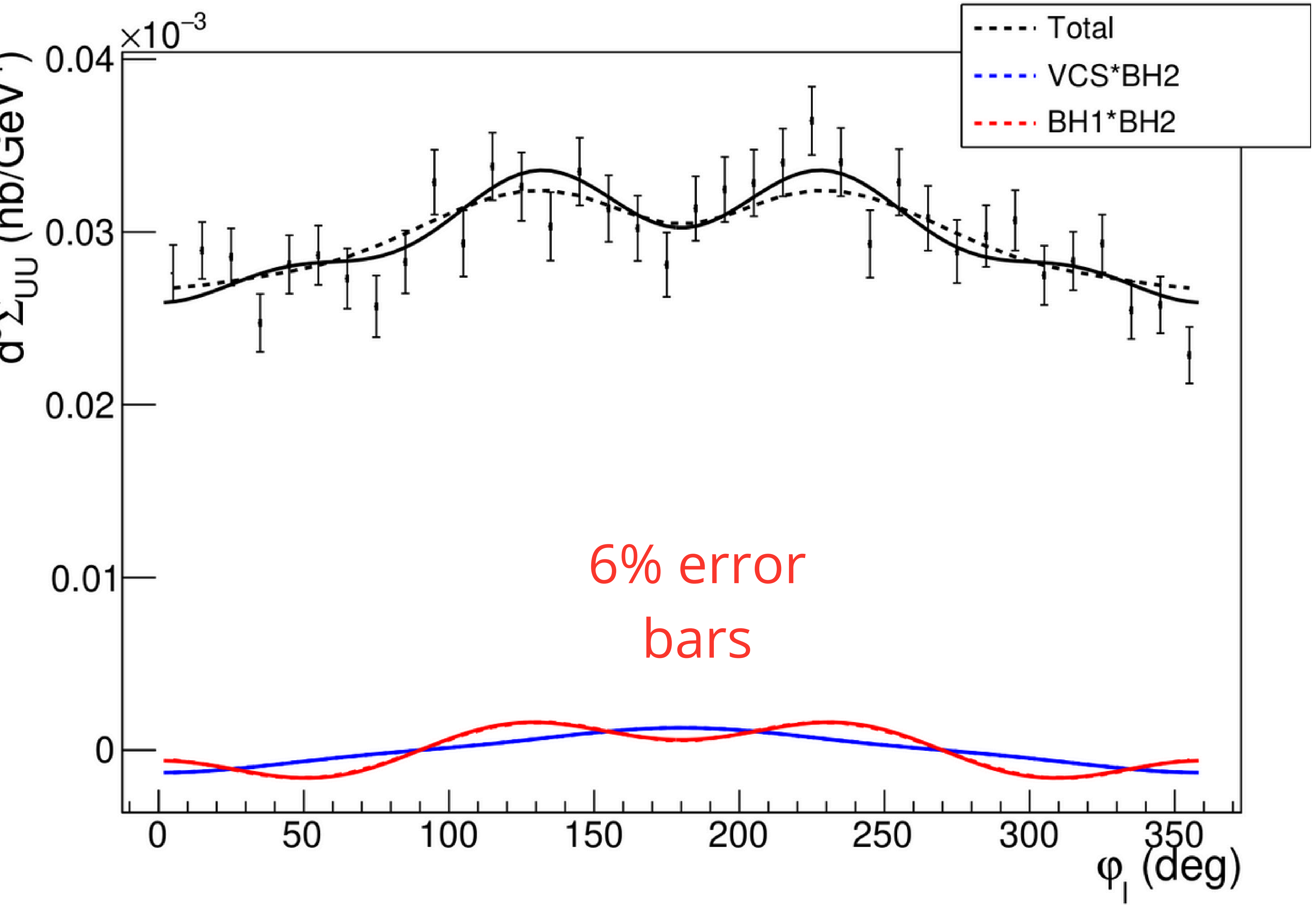
Experimental projection of the cross-section

I fit the theory curves and pseudo-data to the following function

$$\sigma_k = a_k + b_k \cos(\phi) + c_k \cos(2\phi) + d_k \cos(3\phi) + e_k \cos(4\phi)$$

where k=BH1*BH2, VCS*BH2

We are interested in the ‘a’ and ‘b’ coefficients as the BM observable is given by ‘b/2πa’



- Dashed lines are theory predictions
- Solid lines are fits

Experimental projection of the cross-section

We can now compare the extracted value with the true value from the theory fit (blue fit)

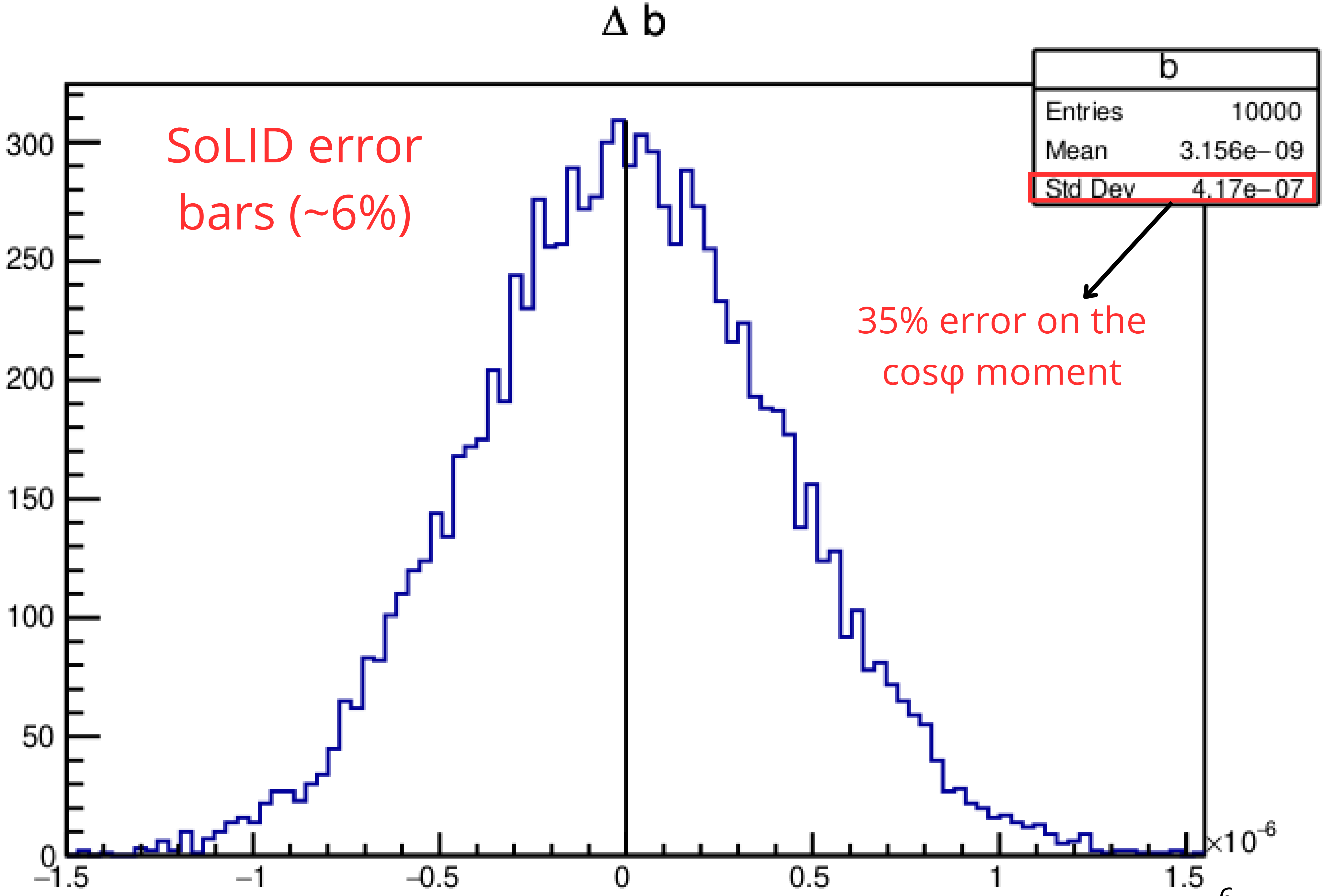
$$\Delta b = b_{VCS*BH2} - b_{True}$$

We repeat this process 10K times to see how Δb distributes

It looks like the cos(φ) moment can be extracted with good precision as:

- Mean of the distribution is at zero
- Standard deviation is small.

$$b_{true} = -1.17337 \times 10^{-6}$$



22% error on the cosφ moment

Experimental projection of the cross-section

What if we weight the cross-section?

$$|\mathcal{T}_{\rm VCS}|^2 = \frac{2\xi^2 e^8}{Q^4 y^2 \tilde{y}^2(\eta^2-\xi^2)} \sum_{n=0}^{2} \{ c_n^{\rm VCS}(\varphi_\ell)\cos(n\phi) + s_n^{\rm VCS}(\varphi_\ell)\sin(n\phi) \}, \quad (97)$$

$$\mathcal{I} = \frac{2\xi(1-\eta)e^8}{y^3\tilde{y}^3(\eta^2-\xi^2)Q^2\Delta^2} \sum_{n=0}^{3} \left\{ \pm \frac{\tilde{y}}{\mathcal{P}_1\mathcal{P}_2(\phi)}[c_n^1(\varphi_\ell)\cos(n\phi) + s_n^1(\varphi_\ell)\sin(n\phi)] + \frac{y}{\mathcal{P}_3\mathcal{P}_4(\varphi_\ell)}[c_n^2(\phi)\cos(n\varphi_\ell) + s_n^2(\phi)\sin(n\varphi_\ell)] \right\}, \quad (98)$$

$$|\mathcal{T}_{\rm BH}|^2 = -\frac{\xi(1-\eta)^2}{y^4\tilde{y}^4\Delta^2 Q^2\eta(\eta^2-\xi^2)} \left\{ \sum_{n=0}^{4} \left(\frac{\tilde{y}^2}{\mathcal{P}_1^2\mathcal{P}_2^2(\phi)}[c_n^{11}(\varphi_\ell)\cos(n\phi) + s_n^{11}(\varphi_\ell)\sin(n\phi)] + \frac{y^2}{\mathcal{P}_3^2\mathcal{P}_4^2(\varphi_\ell)}[c_n^{22}(\phi)\cos(n\varphi_\ell) + s_n^{22}(\phi)\sin(n\varphi_\ell)] \right) \pm \sum_{n=0}^{3} \frac{y\tilde{y}}{\mathcal{P}_1\mathcal{P}_2\mathcal{P}_3\mathcal{P}_4}[c_n^{12}(\varphi_\ell)\cos(n\phi) + s_n^{12}(\varphi_\ell)\sin(n\phi)] \right\}. \quad (99)$$

We might reduce the effect of the prefactors for the cosφ moment extraction

$$\mathcal{O} = \frac{\int d\varphi_\ell \cos\varphi_\ell \mathcal{P}_3\mathcal{P}_4(\varphi_\ell)\ d^5\sigma}{\int d\varphi_\ell \mathcal{P}_3\mathcal{P}_4(\varphi_\ell)\ d^5\sigma}$$

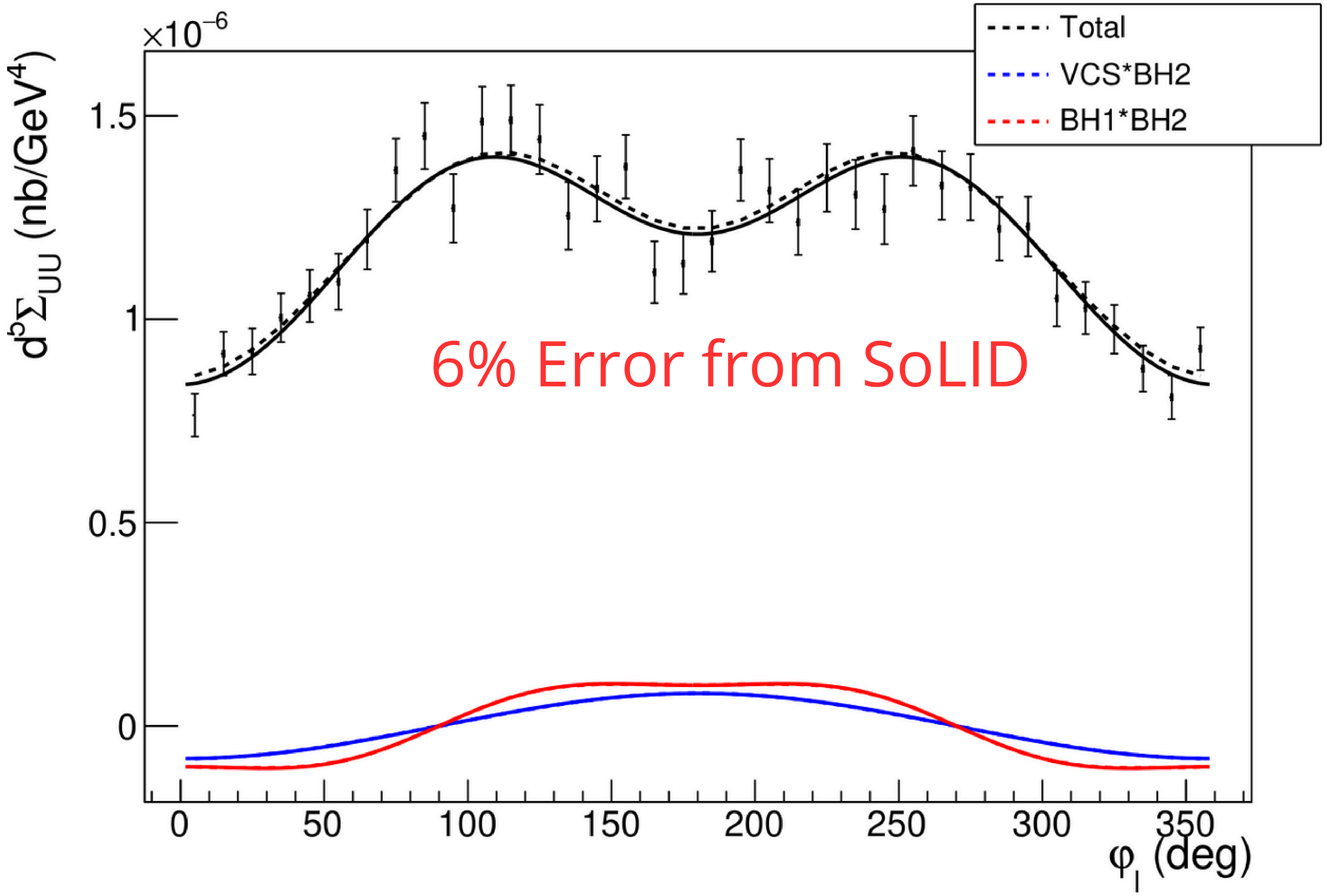
Experimental projection of the cross-section

As a result, the fit can be simplified (only tested on this bin)

$$\sigma_{BH1*BH2} = a_{BH1*BH2} + b_{BH1*BH2}\cos(\phi) + \cancel{c_{BH1*BH2}\cos(2\phi)} + d_{BH1*BH2}\cos(3\phi) + \cancel{e_{BH1*BH2}\cos(4\phi)}$$

$$\sigma_{VCS*BH2} = a_{VCS*BH2} + b_{VCS*BH2}\cos(\phi) + \cancel{c_{VCS*BH2}\cos(2\phi) + d_{VCS*BH2}\cos(3\phi) + e_{VCS*BH2}\cos(4\phi)}$$

$$\sigma_{Tot} = a_{Tot} + b_{Tot}\cos(\phi) + c_{Tot}\cos(2\phi) + d_{Tot}\cos(3\phi) \cancel{+ e_{Tot}\cos(4\phi)}$$



Now we repeat the process

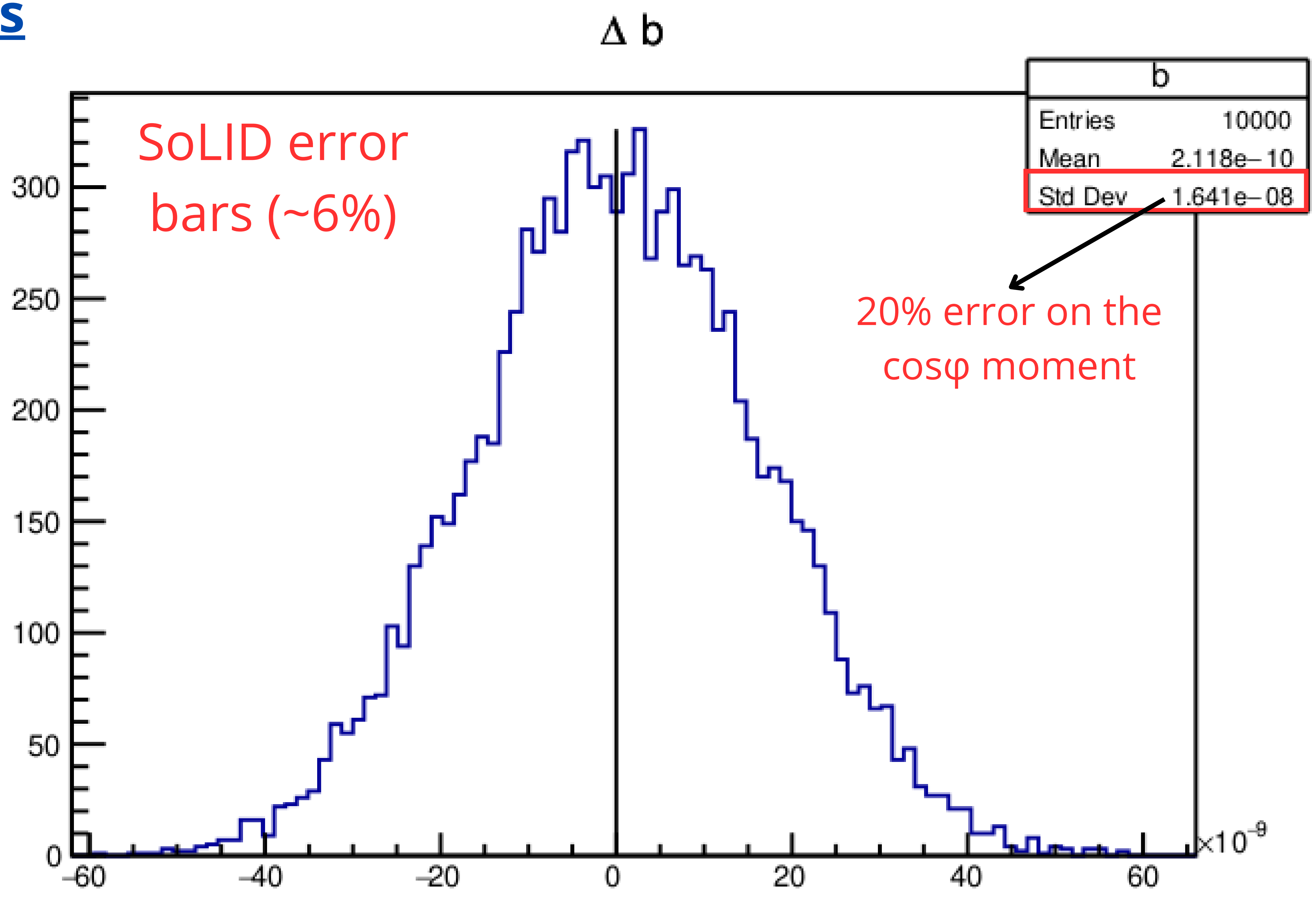
We repeat this process 10K times to see how Δb distributes

$$\Delta b = b_{VCS*BH2} - b_{True}$$

It looks like the cos(φ) moment can be extracted with good precision as:

- Mean of the distribution is at zero
- Standard deviation is small.

$$b_{true}^{Weighted} = -8.01826 \times 10^{-8}$$



Real part of CFF

Regarding asymmetries I think I understood the relation

$$A^{\cos\varphi} = \frac{\int_{\pi/4}^{3\pi/4} \sin\theta_{\mu^-} d\theta_{\mu^-} \int_0^{2\pi} d\varphi_{\mu^-}\ 2\cos\varphi_{\mu^-}\ d\sigma(\theta_{\mu^-},\varphi_{\mu^-})/d\Omega_{\mu^-}}{\int_{\pi/4}^{3\pi/4} d\theta_{\mu^-} \int_0^{2\pi} d\varphi_{\mu^-}\ d\sigma(\theta_{\mu^-},\varphi_{\mu^-})/d\Omega_{\mu^-}} .$$

Here we explicitly extract the cosφ moment

$$A_{FB}(\theta,\phi) = \frac{d\sigma(\theta,\phi) - d\sigma(180^\circ - \theta, 180^\circ + \phi)}{d\sigma(\theta,\phi) + d\sigma(180^\circ - \theta, 180^\circ + \phi)}$$

$$A_{FB}(\theta_0,\phi_0) = \frac{-\frac{\alpha_{em}^3}{4\pi s^2}\frac{1}{-t}\frac{m_p}{Q'}\frac{1}{\tau\sqrt{1-\tau}}\frac{L_0}{L}\boxed{\cos\phi_0}\frac{(1+\cos^2\theta_0)}{\sin(\theta_0)}\mathrm{Re}\tilde{M}^{--}}{d\sigma_{BH}},$$

In TCS (thus DDVCS), the FB projects the cosφ term

Thus, they might be the same thing (up to integration)

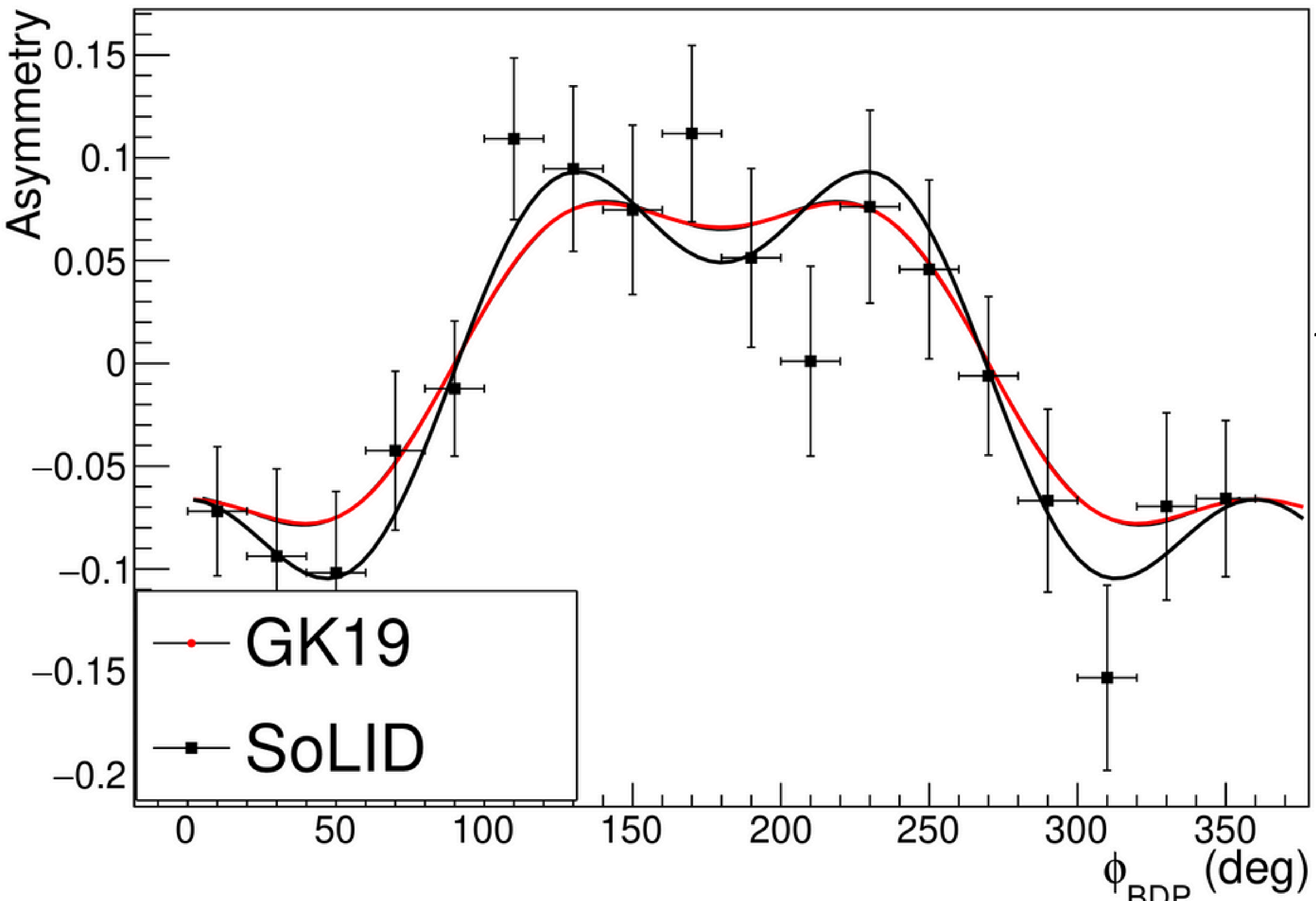
I want to remove the theta dependence of the FB

Constructing a φ-modulated observable

Given the following definition of FB, it projects the cos(φ) and cos(3φ) terms

$$A_{FB} = \frac{N(\phi) - N(\pi + \phi)}{N(\phi) + N(\pi + \phi)}$$

$$\frac{d^4\sigma_{INT}}{dQ'^2 dt d\Omega} = -\frac{\alpha_{em}^3}{4\pi s^2}\frac{1}{-t}\frac{m_p}{Q'}\frac{1}{\tau\sqrt{1-\tau}}\frac{L_0}{L}[\cos(\phi)\frac{1+\cos^2(\theta)}{\sin(\theta)}\mathrm{Re}\tilde{M}^{--} - \cos(2\phi)\sqrt{2}\cos(\theta)\mathrm{Re}\tilde{M}^{0-} + \cos(3\phi)\sin(\theta)\mathrm{Re}\tilde{M}^{+-} + O(\frac{1}{Q'})], \quad (1.76)$$



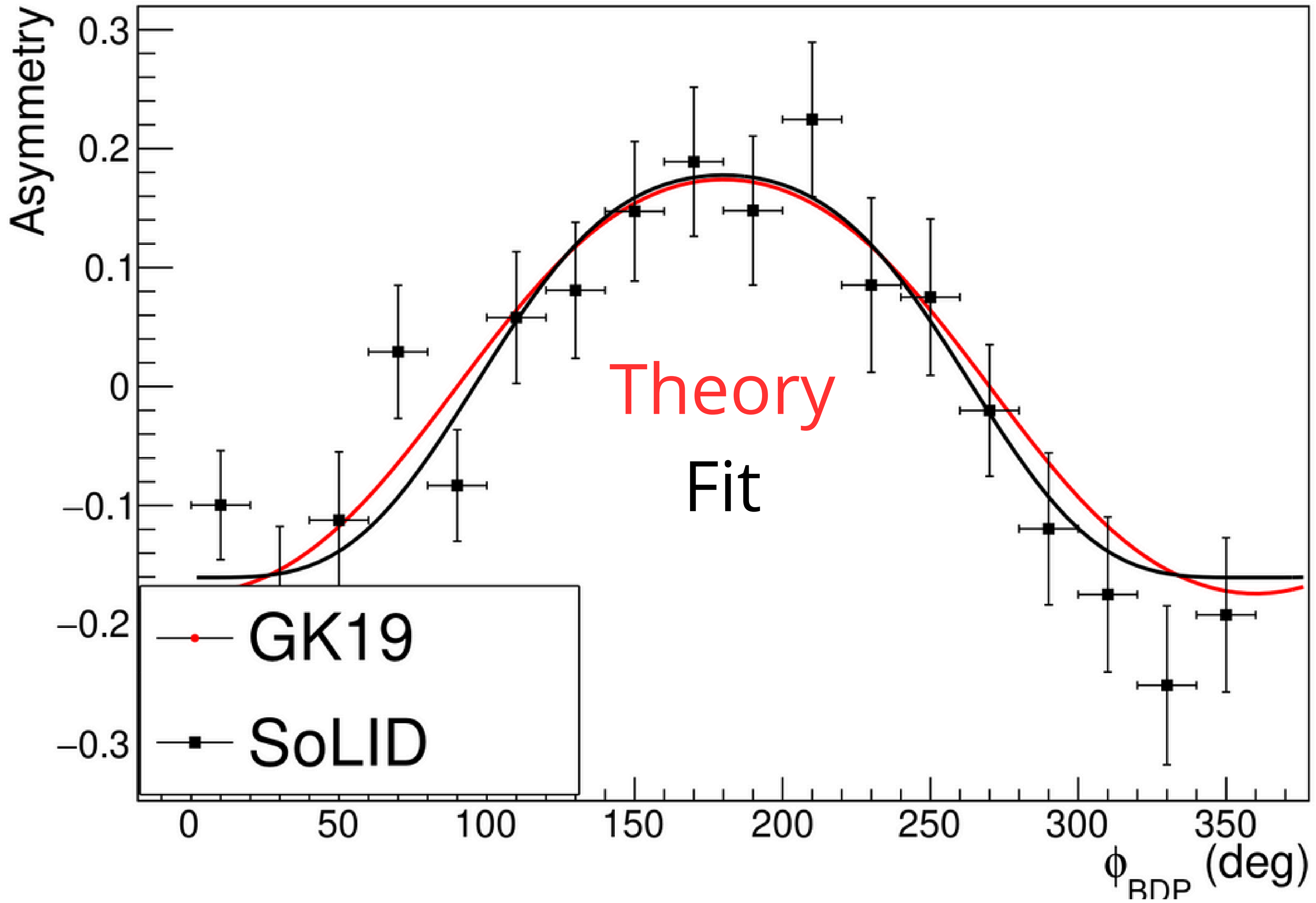
the cos(3φ) has a strong contribution though

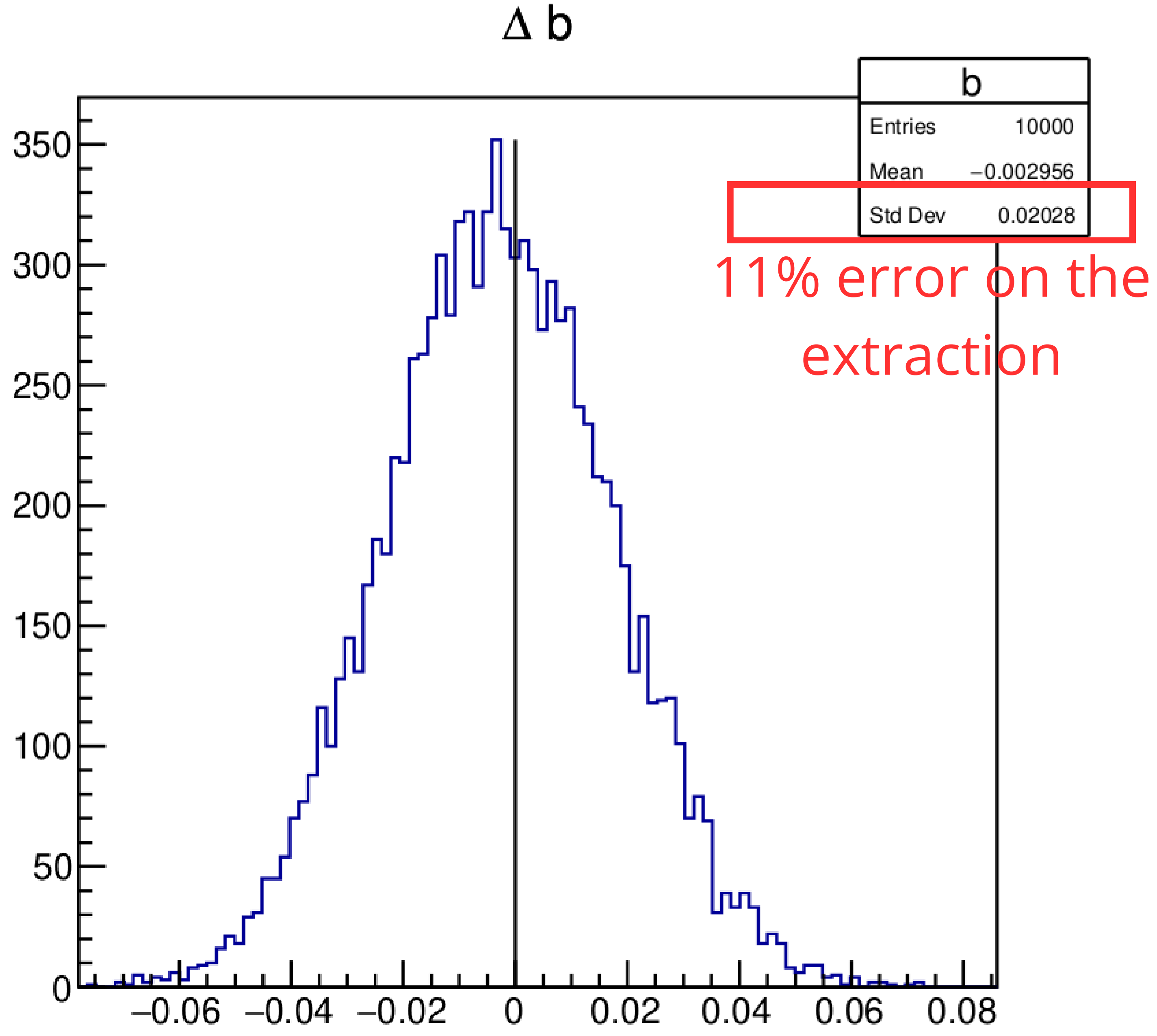
Constructing a φ-modulated observable

But, using the modified cross-section we obtain an almost clean cosφ modulation

$$\mathcal{P}_3\mathcal{P}_4(\varphi_\ell)\ d^5\sigma$$

$$b_{true}^{Weighted} = -0.17788$$





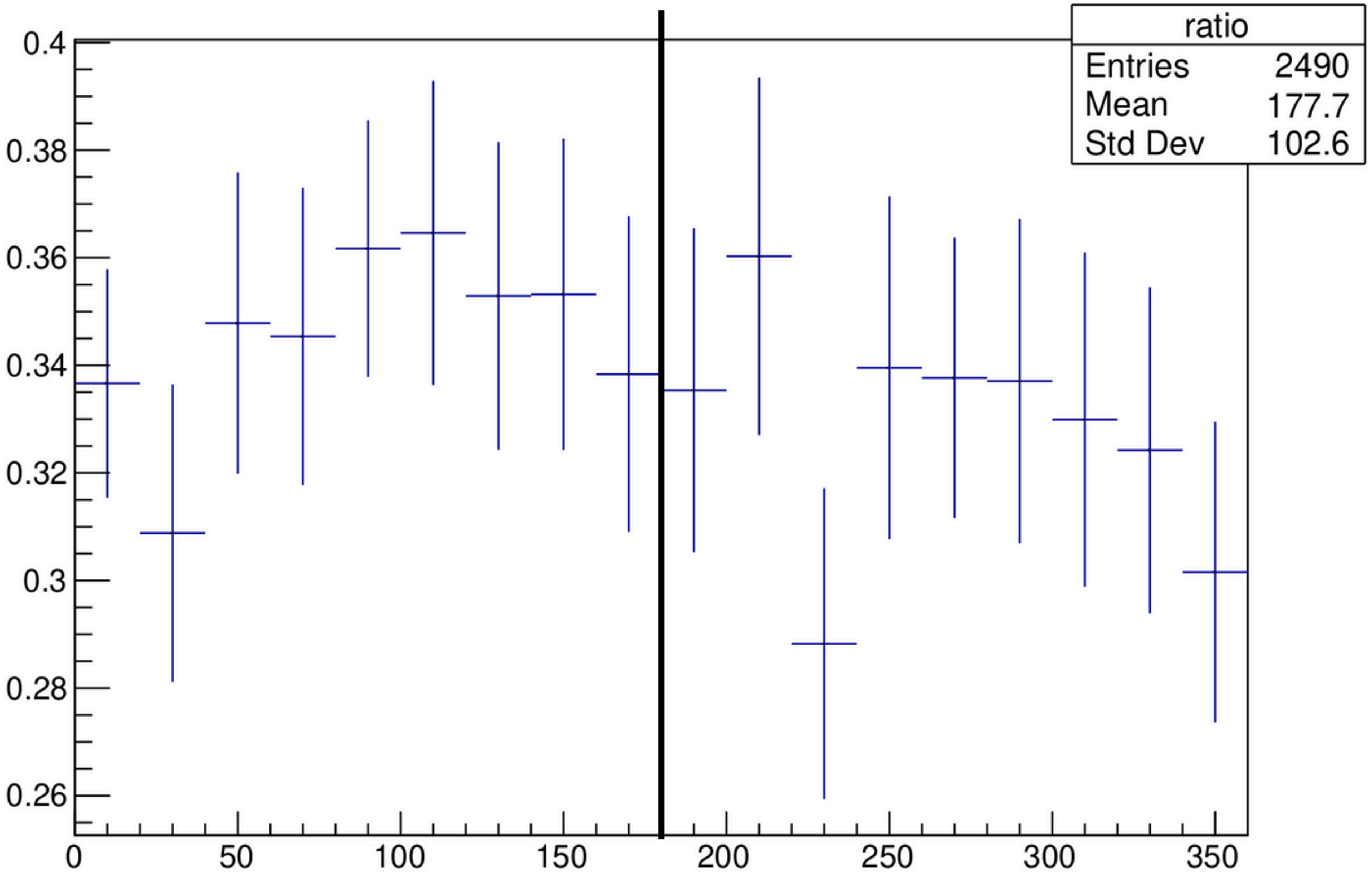
From the experimental point of view:

- We extract the cross-section and weight each event with $P_3P_4(\varphi)$
- Thus, we maximize statistics by not binning in theta

Constructing a φ-modulated observable

The main affecting factor is the acceptance correction.
For my working bin it looks like this

Reconstructed / Generated



It is not constant but it does not strongly fluctuate neither

Thanks