# $B^0 \to D^\star l\nu$ analysis

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Analysis meeting
September 9, 2022

# Motivation

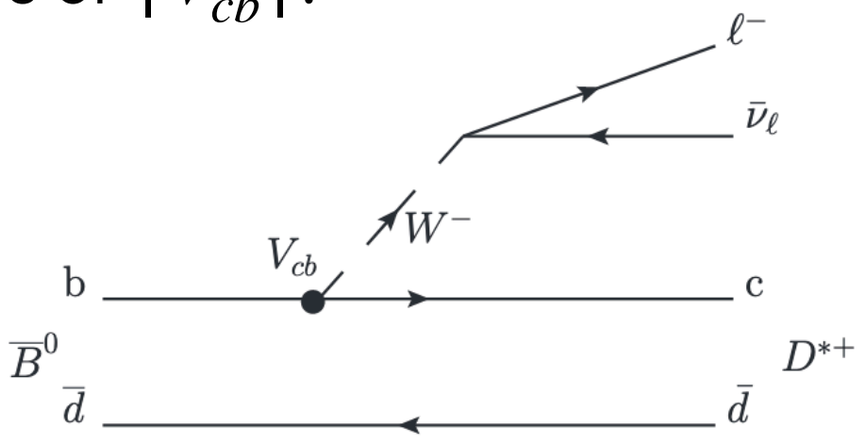
$|V_{cb}|$ is the magnitude of the weak-interaction coupling between *b* and c quarks.

$|V_{cb}|$ is an important SM benchmark parameter that impacts also BSM interpretations of suppressed B decays measurements.

Two different approaches lead to two different value of $|V_{cb}|$:

$|V_{cb}| = (42.2 \pm 0.8) \times 10^{-3}$ (using $B \to X_c l\nu$ decays)
(inclusive approach)

$|V_{cb}| = (39.5 \pm 0.9) \times 10^{-3}$ (using $B \to D^{(*)} l\nu$ decays)
(exclusive approach)




Calls for a deeper investigation of the two methods.

Focus on the exclusive approach: the determination of $|V_{cb}|$ from this method relies on the description of strong-interaction effects for the *b* and *c* quarks bound in mesons (modeled into effective quantities called “form factors”).

**Final goal**: provide the first model-independent measurement of the form factors on $B^0 \to D^\star l\nu$ using the full Belle II data set collected so far (~ 430 $fb^{-1}$), to yield a better determination of $|V_{cb}|$.

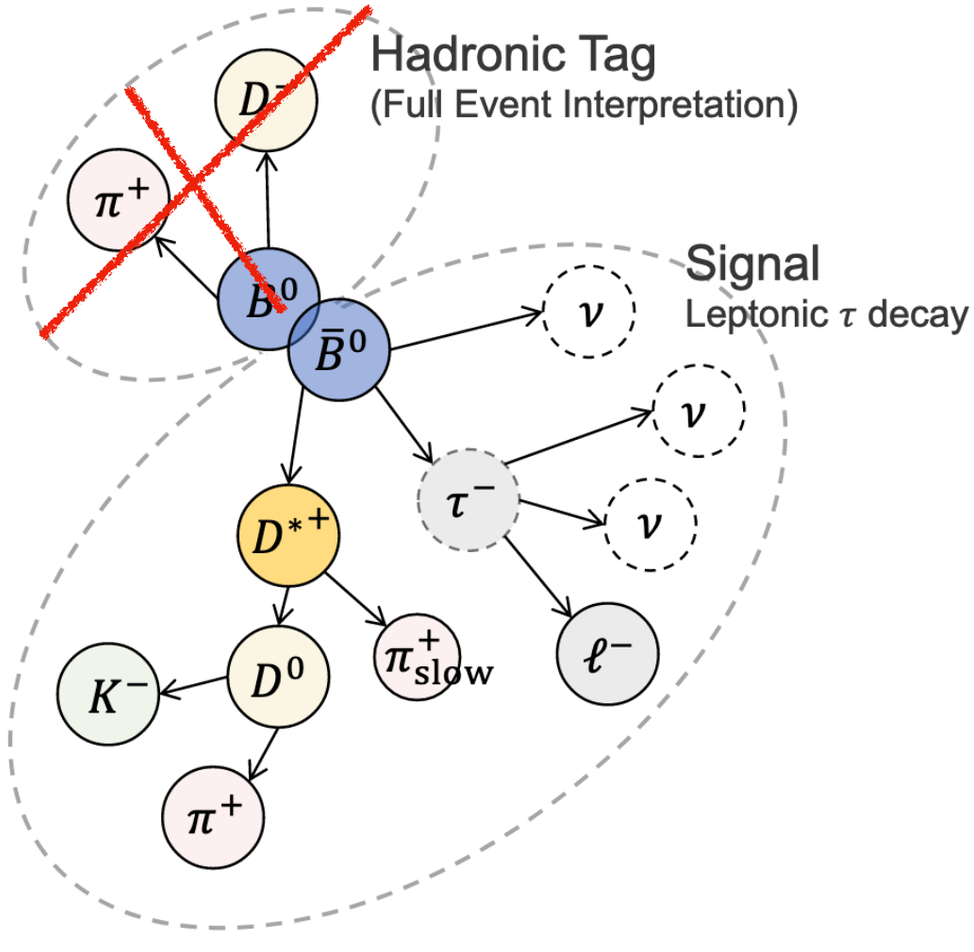
# Untagged analysis

The form factors are functions of the recoil energy of the D meson in the B rest frame.

$$w = \frac{E_D}{m_D}$$

To measure $w$, we need to know the B momentum (to boost the D in the B rest frame).

Neutrino is not reconstructed → **kinematics is not closed** → cannot reconstruct the B momentum.




Two different approaches:

- Reconstruct the other B in the $e^+e^- \to Y(4s) \to B\bar{B}$ decay. From momentum conservation in the CM, the B signal momentum can be extracted: **low efficiency**, **high resolution**.

- Don't reconstruct the other B, approximate kinematics: **high efficiency**, **low resolution**.

I expect my precision to be limited by sample size → I use the second approach.

# Methods

We know the magnitude of B momentum in the CMS but not its direction. We can exploit these two informations:

A. B vector momentum should lie on a cone around the $D^{*}l$ vector-momentum with a known opening angle (from E-p conservation assuming 1 missing neutrino) ;

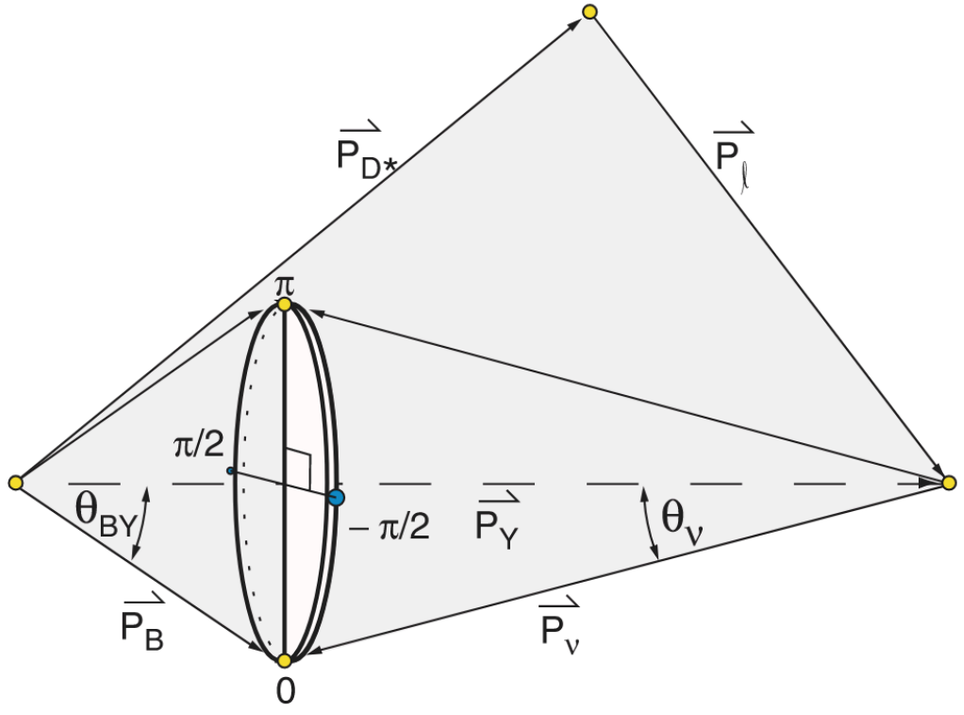
B. B meson is more likely to be perpendicular to the beams (from $Y(4S)$ polarisation).

Three methods to estimate the B's momentum direction:

1. Average a number of random directions by weighting them with  B) probability;

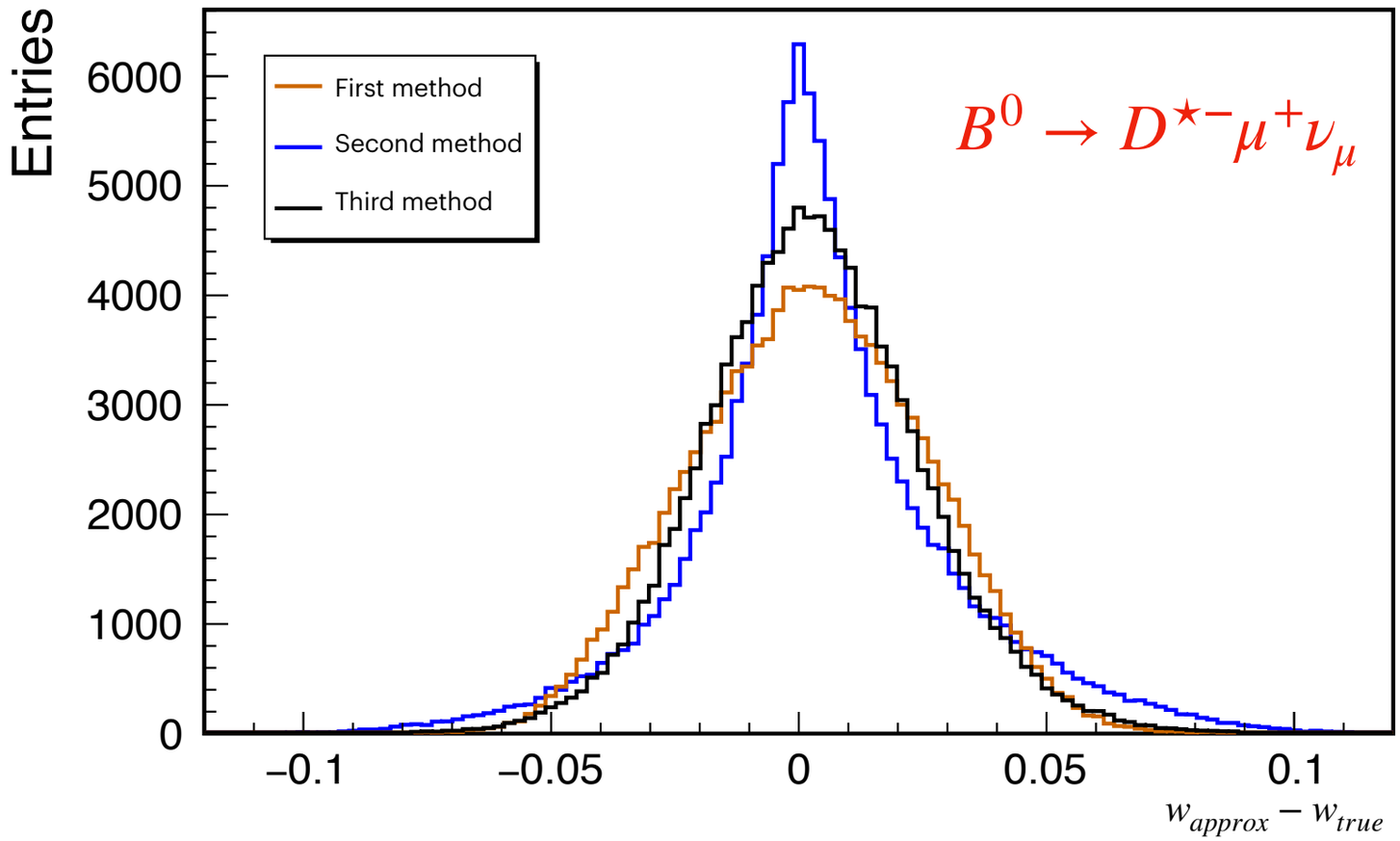
2. Reconstruct the other B inclusively and look for the direction on the cone closest to the opposite direction of the other B.

3. Arithmetic average of 1. and 2. solutions.



# Resolution plots

The first step of this study is to determine the resolution of the kinematic variables for each method using a simulation .

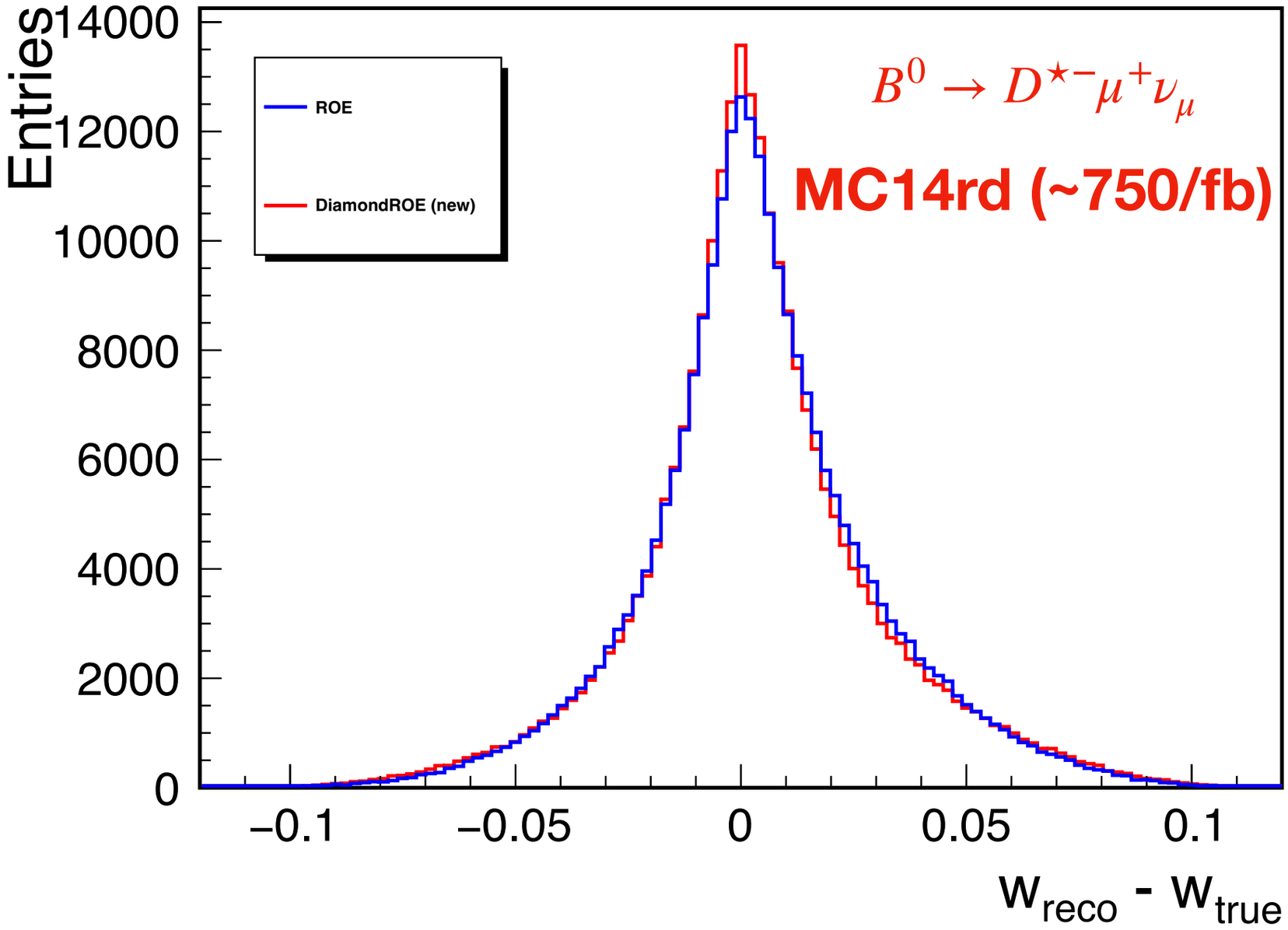



**Second method gives a better result.**

**Next step**: try adding information of the other B and combining it into a MVA regression algorithm to see if we get something better.

# Resolution plots: ROE vs new Diamond+ROE

I modified the classical Diamond+ROE method by taking, for each event, the $\phi_i$ of B that has the highest weight. I compared the new resolution plots with the resolution plots obtained using the ROE method.



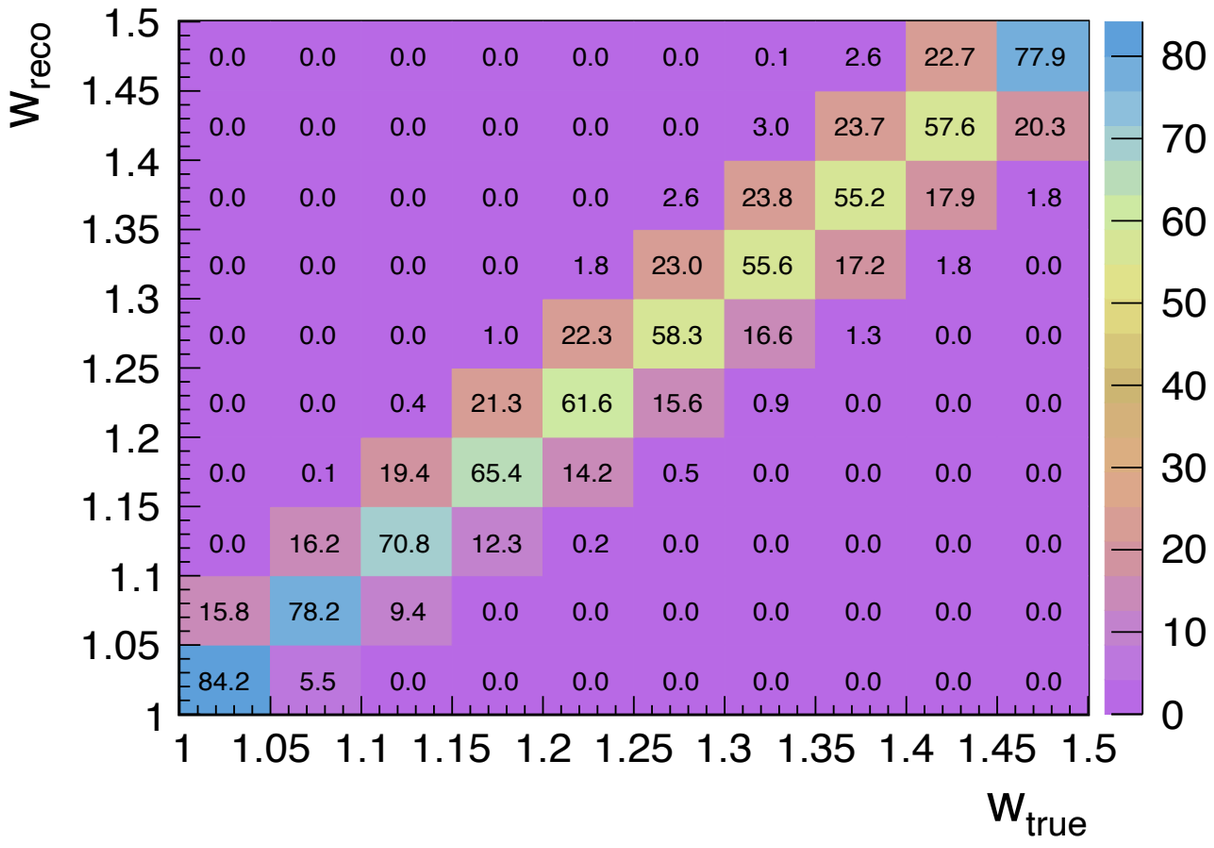

The new method reproduces a little better results respect to the ROE method.

# Migration matrix: ROE vs new Diamond+ROE

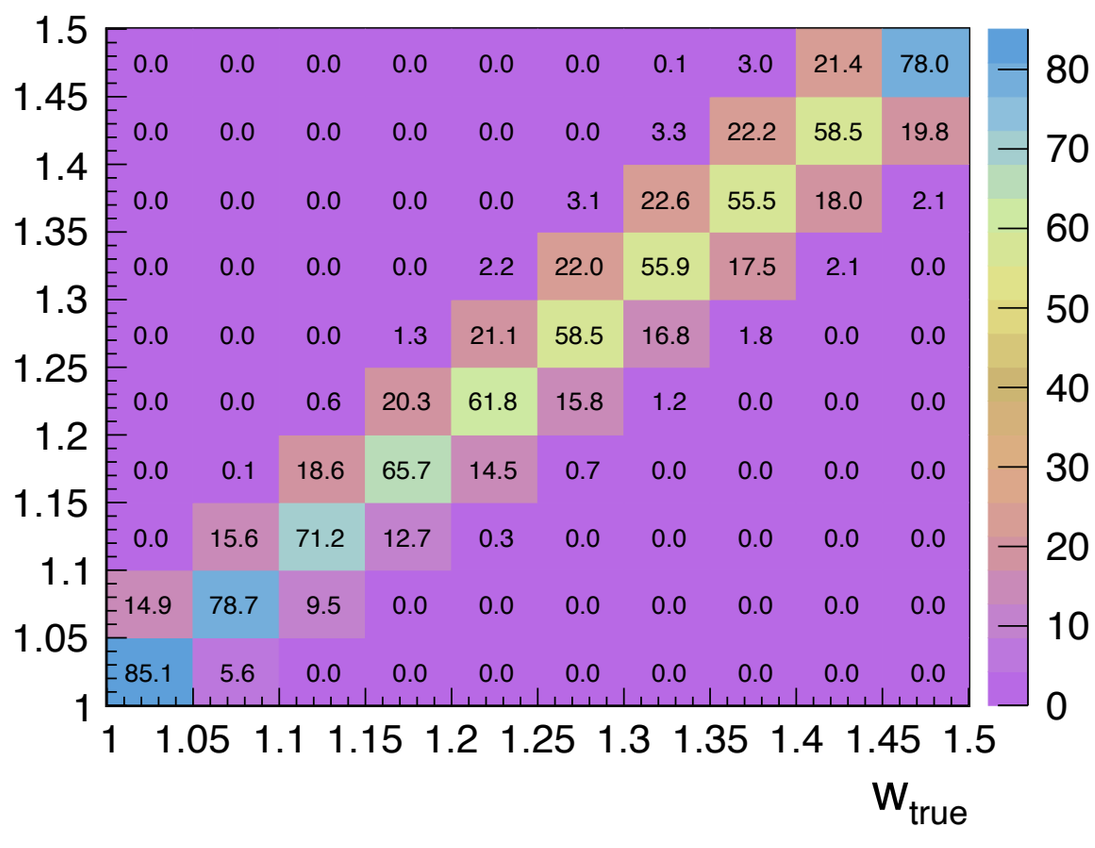
To evaluate the performance of the two methods we can see at the migration matrices of the kinematic variables. The migration matrix elements are defined as conditional probabilities:

$$\mathcal{M}_{ij} = \mathcal{P}(\text{measured value in bin } i | \text{ true value in bin } j)$$

**ROE method**




**New diamond + ROE method**

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# Next steps

- Start to reconstruct $B^0 \to D^{\star -} e^+ \nu_e$ (jobs are running on grid);
- Repeat the resolution plots/migration matrices for the $B^0 \to D^{\star -} e^+ \nu_e$;
- Consider the leptonID and fake rates corrections (in progress);
- Find possible correlations between the $w_{true}$ and other possible kinematic variables. (spoiler: found a correlation between $w_{true}$ and $E_t^{CMS}(D*)$);
- Found possible correlations between the reconstructed $\phi_i$ (i=1,2...10) and $\phi_{true}$ . (diamond method → I'm working with Matteo);
- Compare the resolution plots/migration matrices between MC14ri and MC15ri: no differences observed;
- Finish the internal note (Instrumental Asymmetries) (deadline: Sunday/Monday).

# Backup

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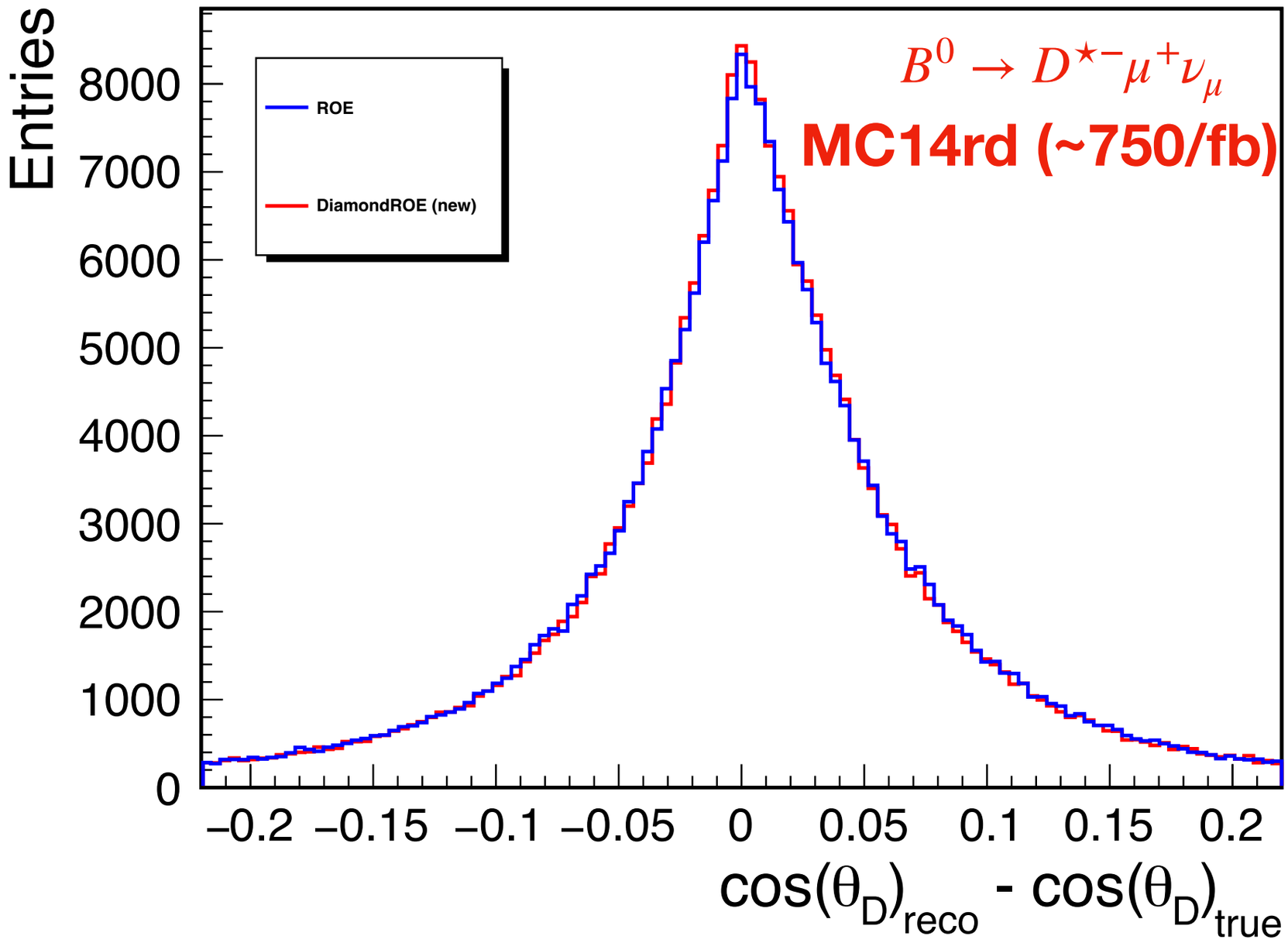


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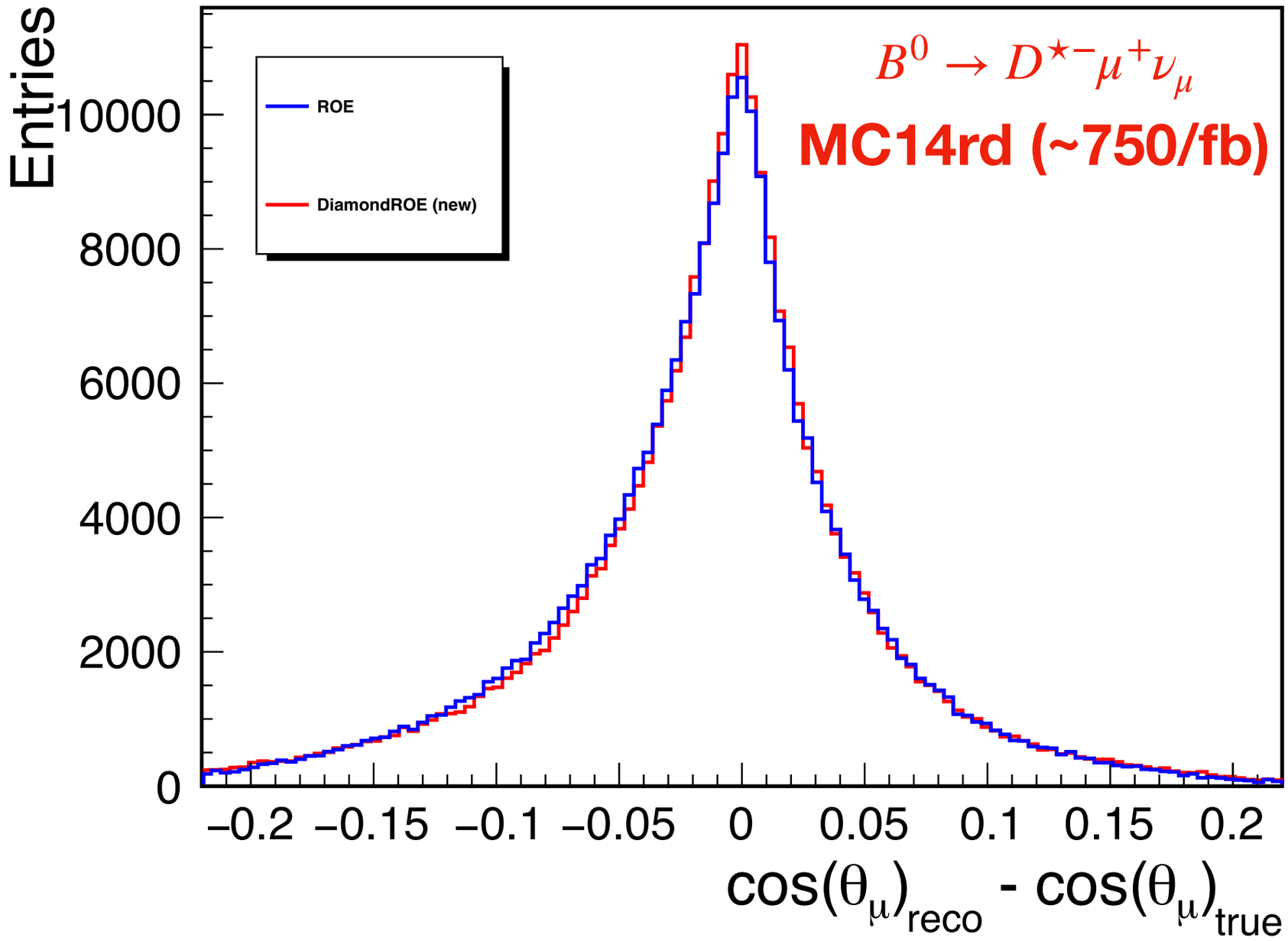


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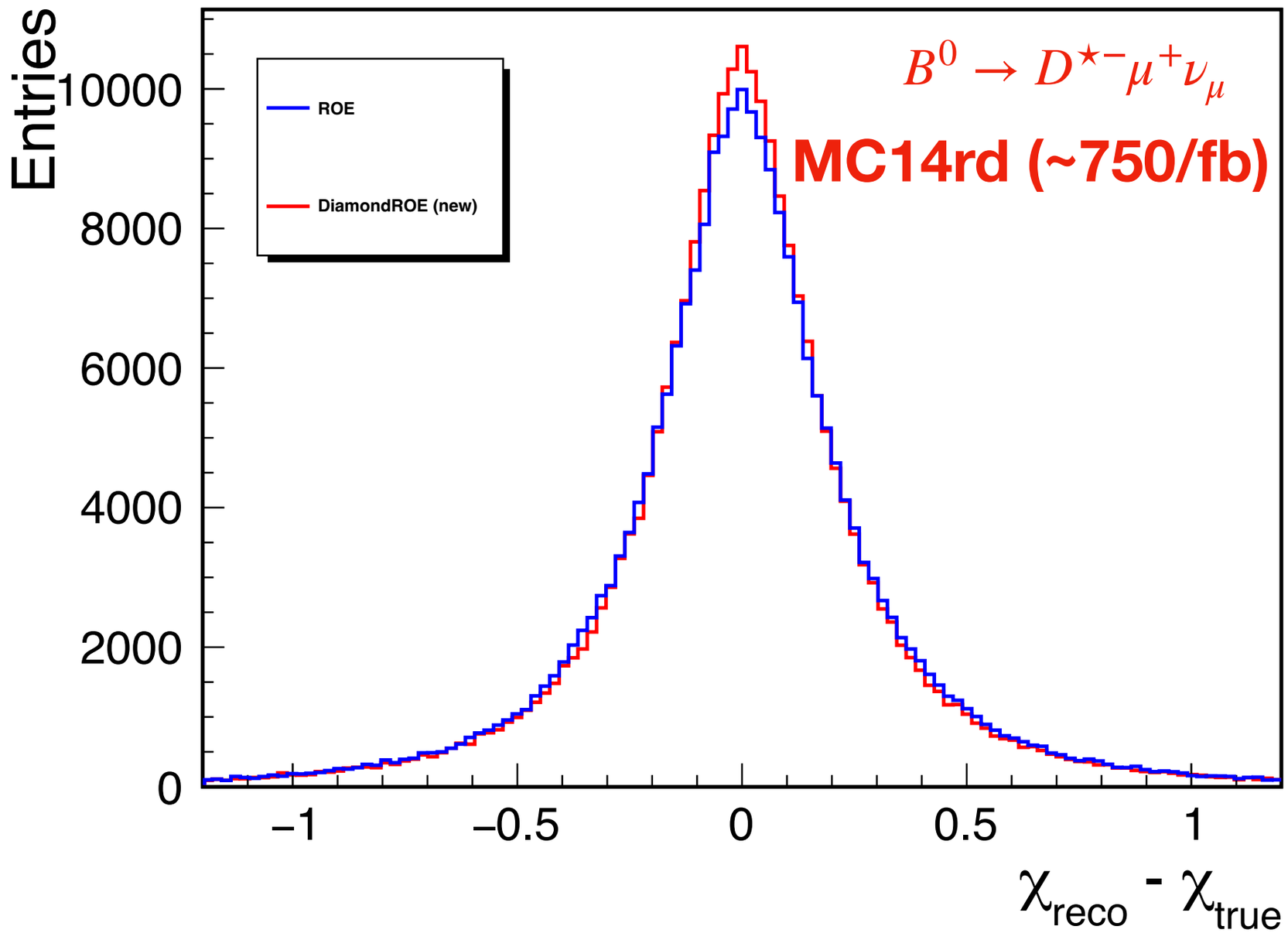


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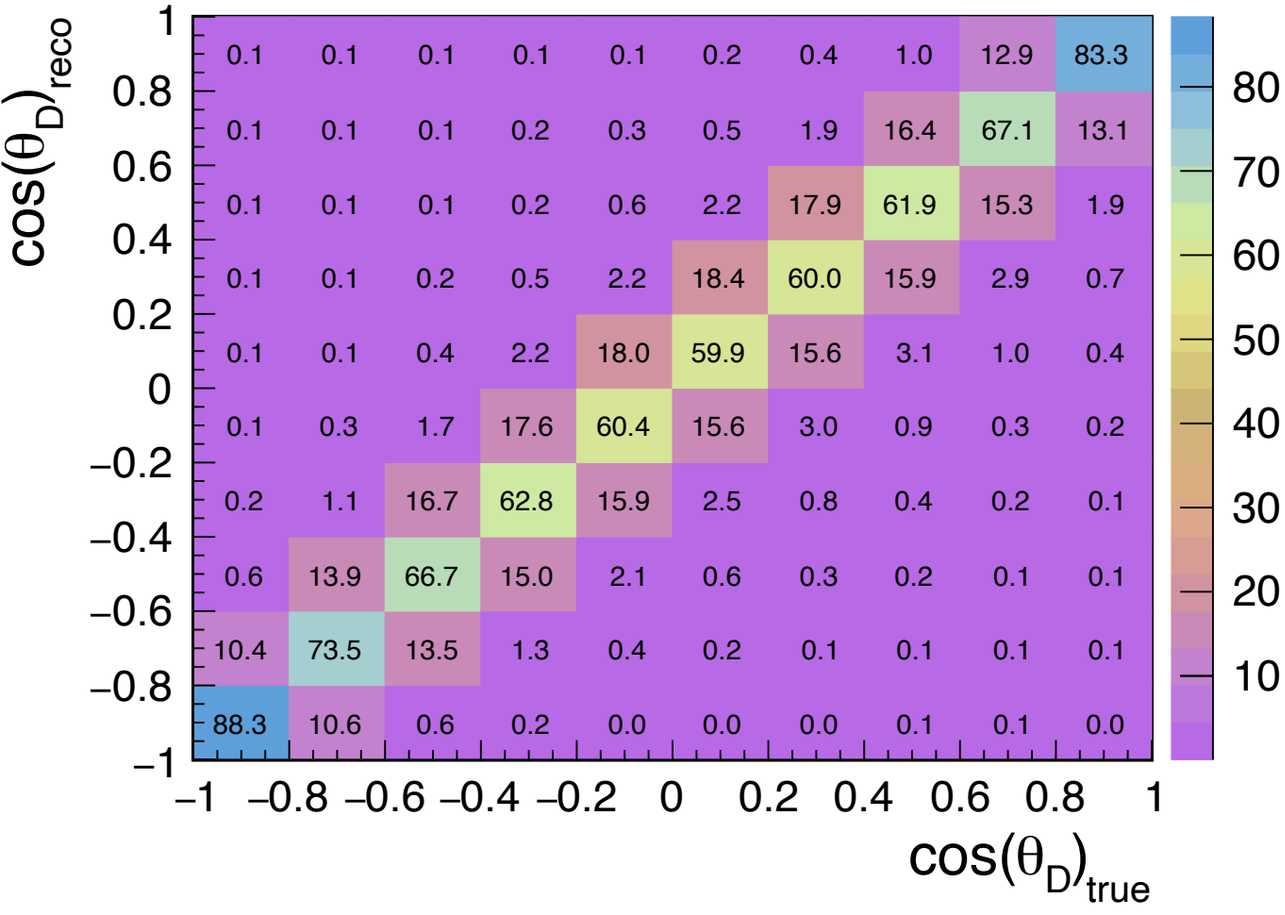


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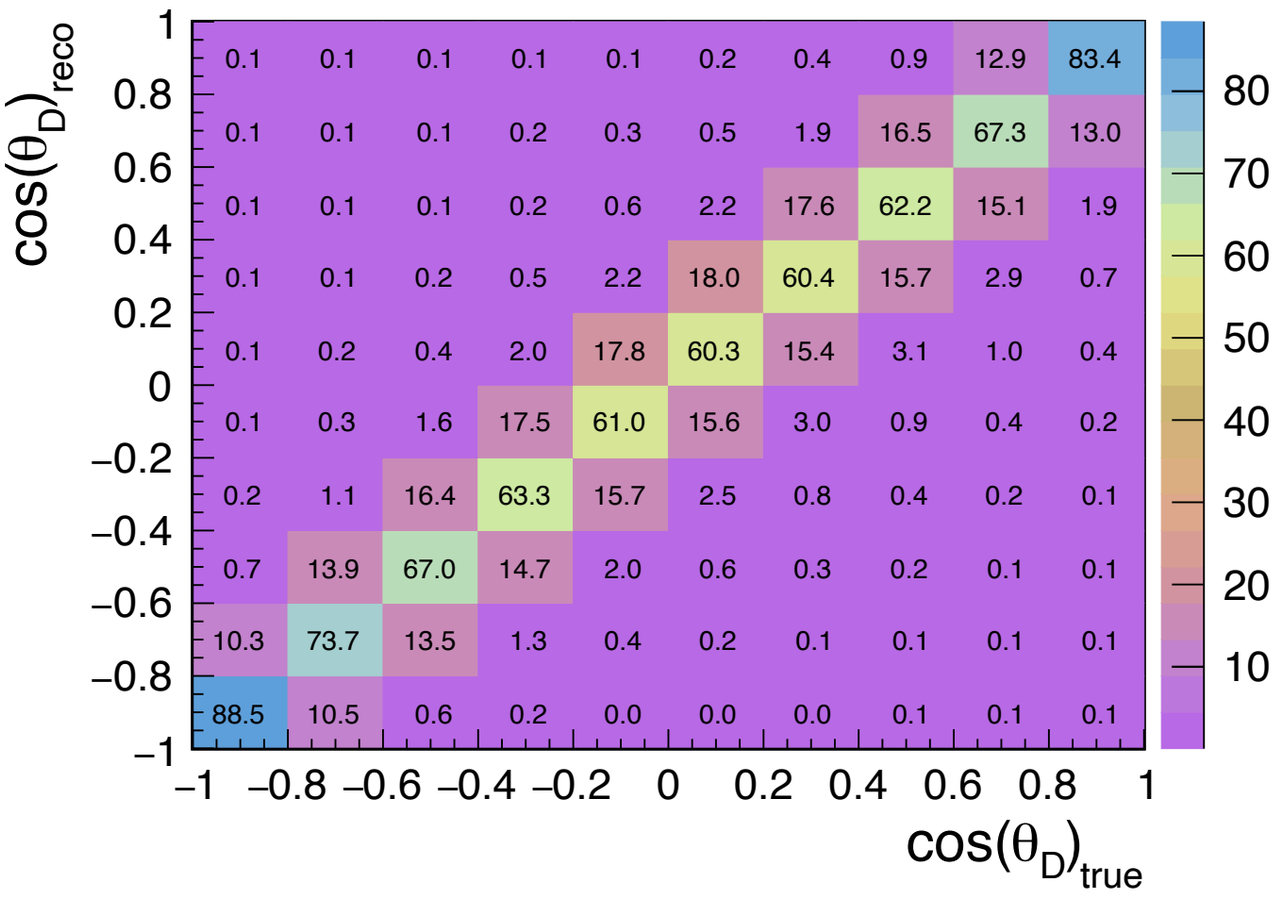


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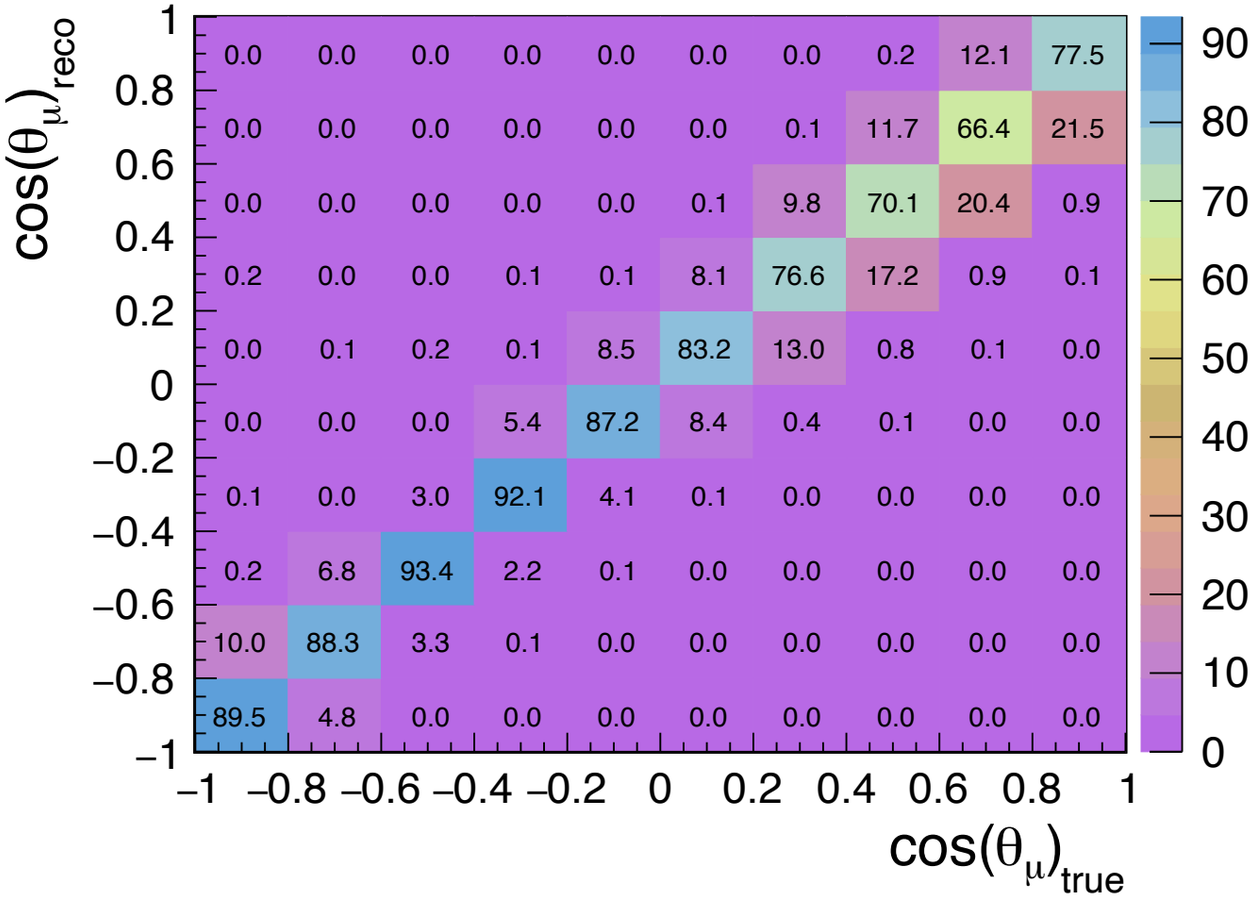


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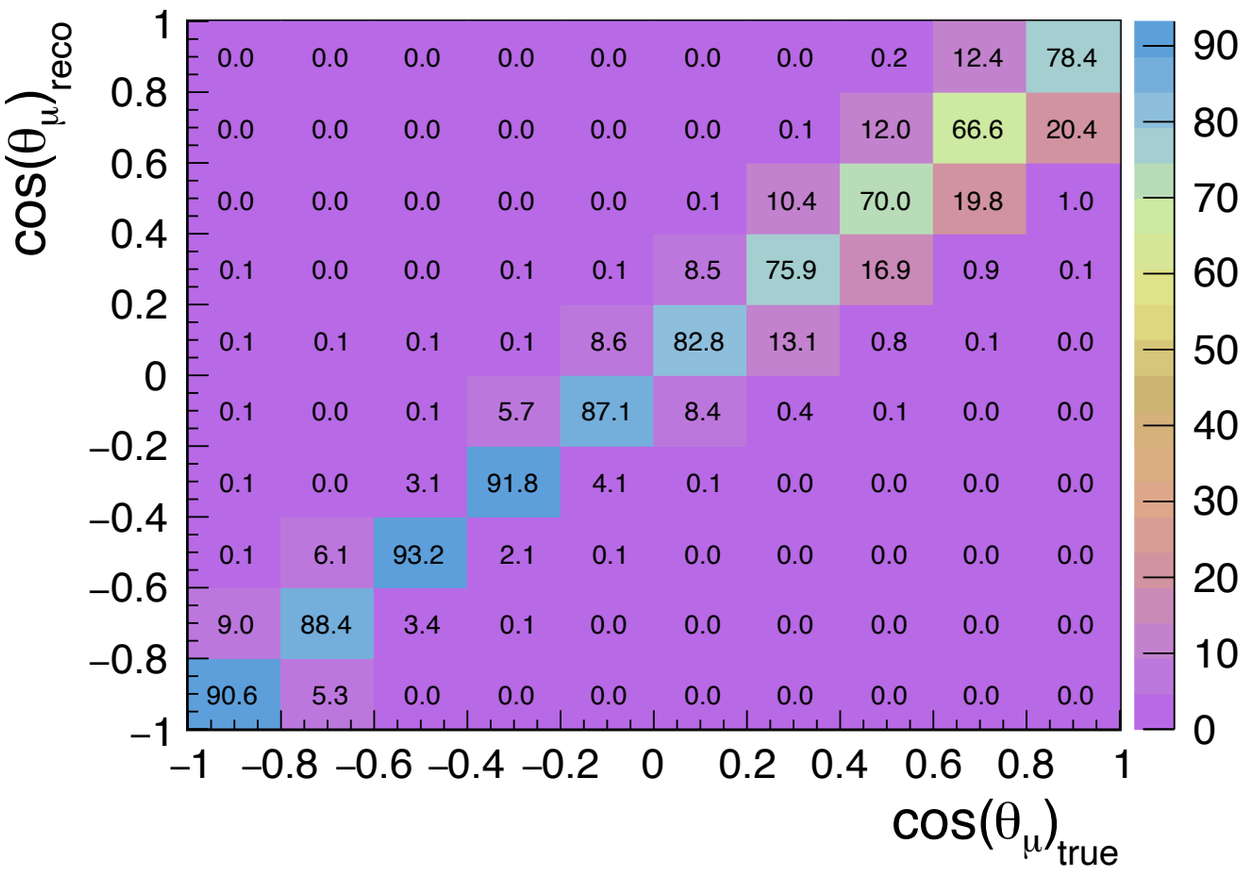


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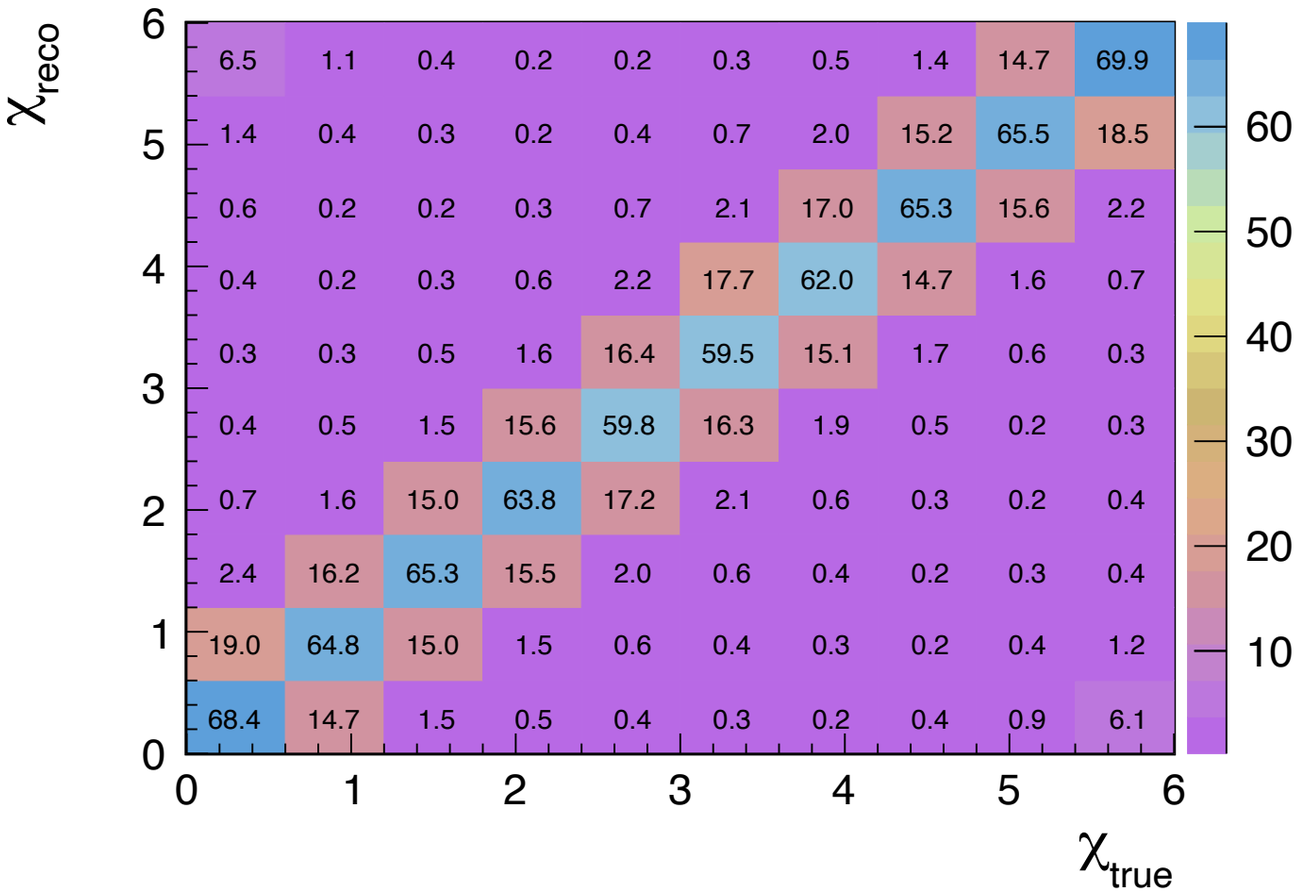


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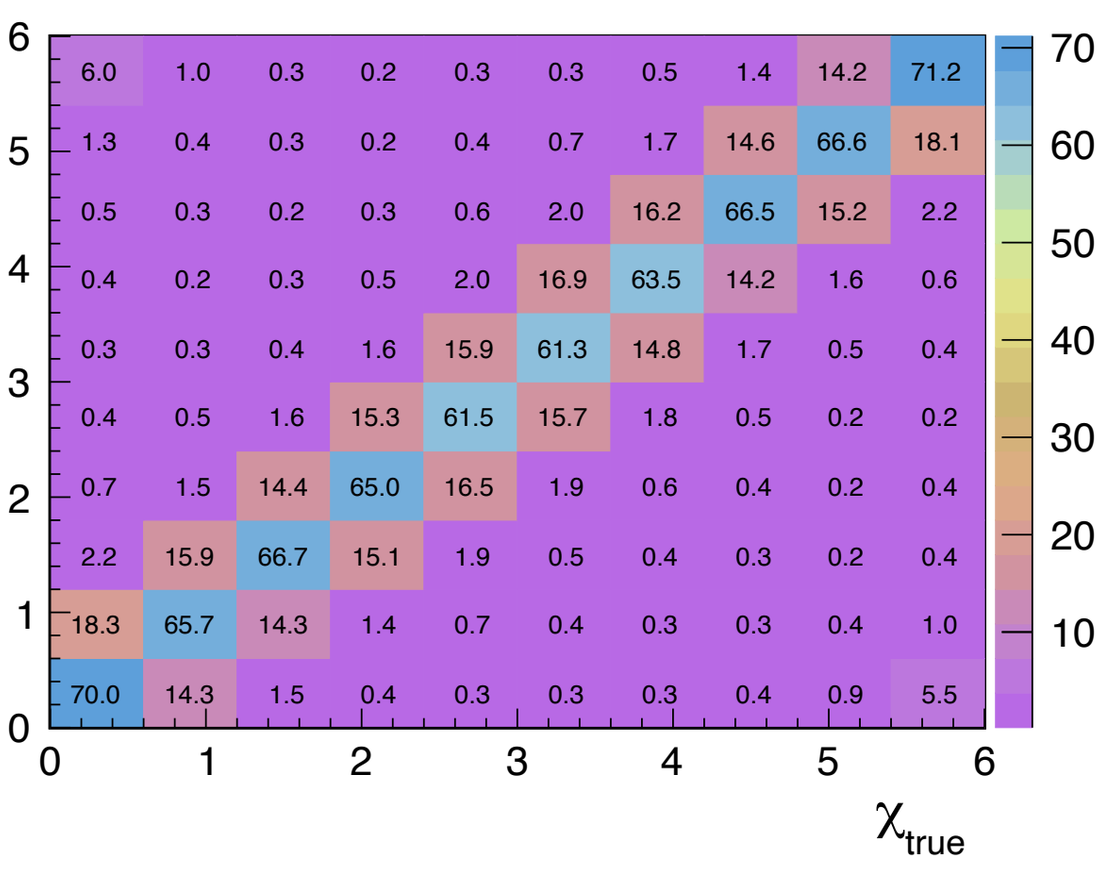


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# $w_{true}$ vs $E_t^{CMS}(D^*)$