Studying Annihilation Distributions

Adriano Del Vincio, Germano Bonomi,
Simone Stracka

University of Brescia, INFN Pisa

07/11/2023

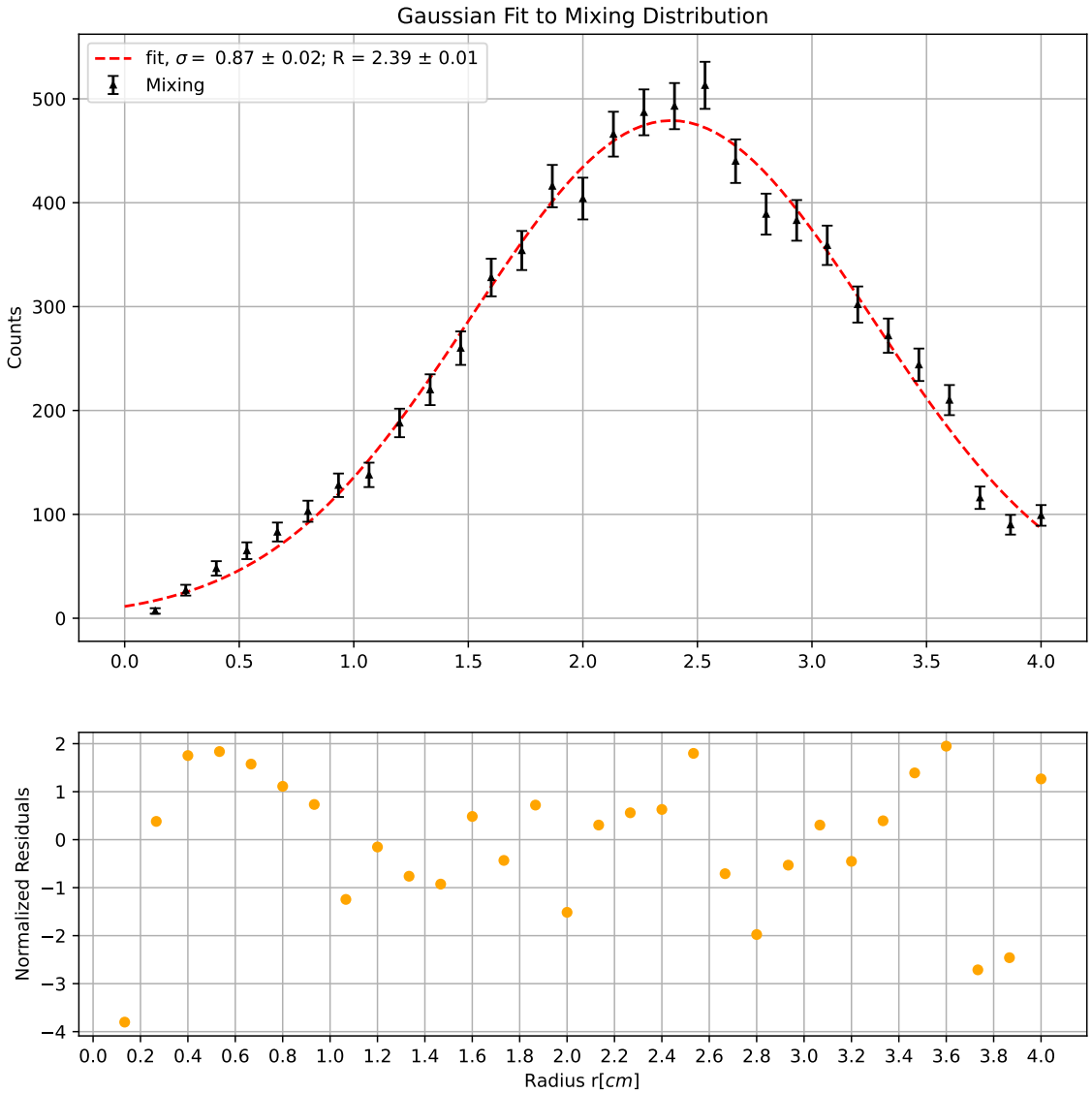
I tried to fit the distributions the radial distribution of the anti-hydrogen annihilation with analytic models. This should improve the results, avoiding statistical fluctuations: The models are listed below:

- Pdf Mixing: the Normal distribution.
- Pdf Uwlosses: Rayleigh distribution $\frac{r}{\sigma^2} e^{-\frac{r^2}{2\sigma^2}}$.
- Pdf Cosmic: $k \cdot x$.

The factor k is the normalization constant. The Mixing, UW losses and cosmic data are fitted and the result are shown in the following slides.

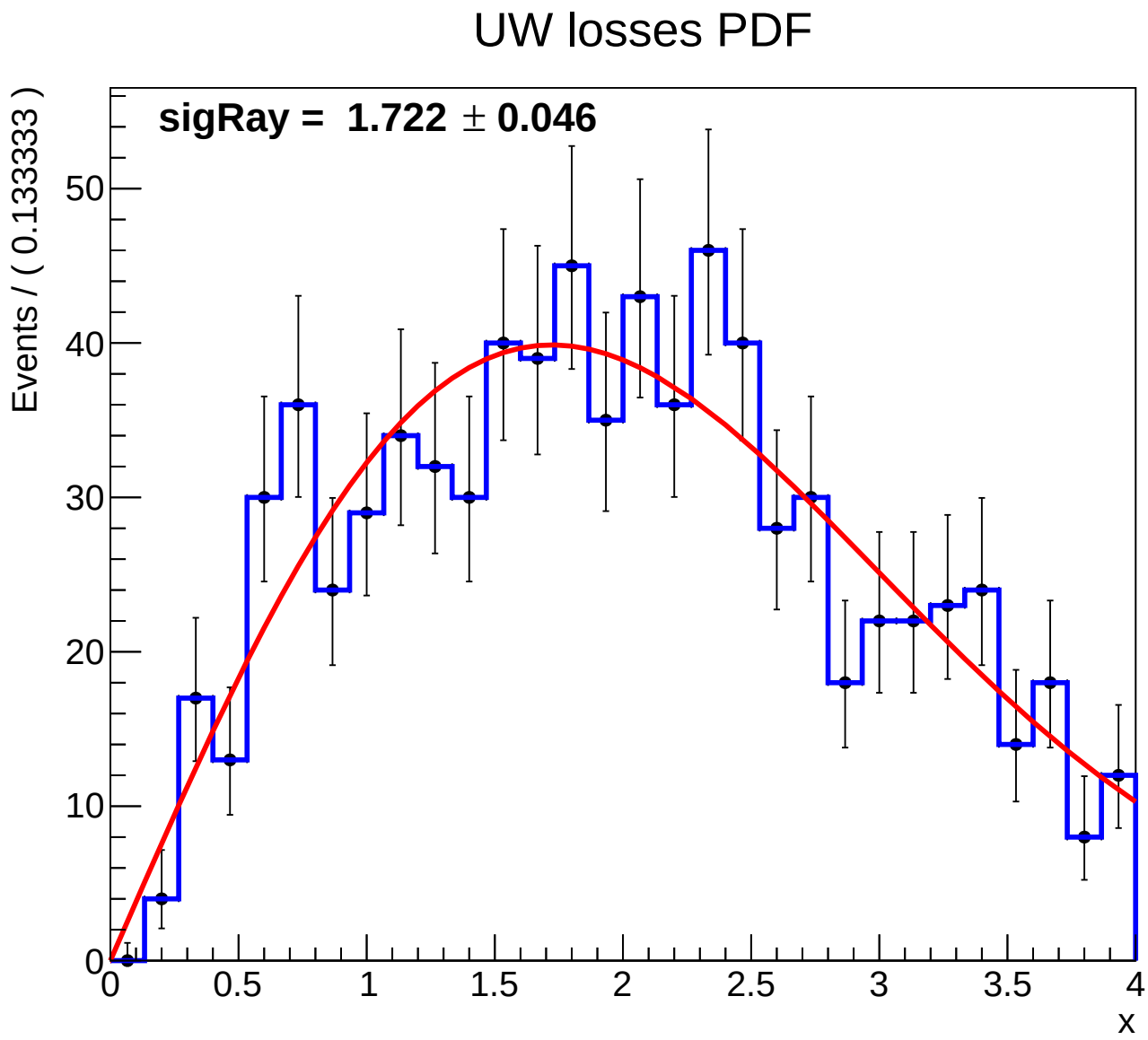
MIXING

Mixing dataset represents almost pure data of anti-hydrogen annihilation on the walls. The radius distribution is fitted with a Gaussian.



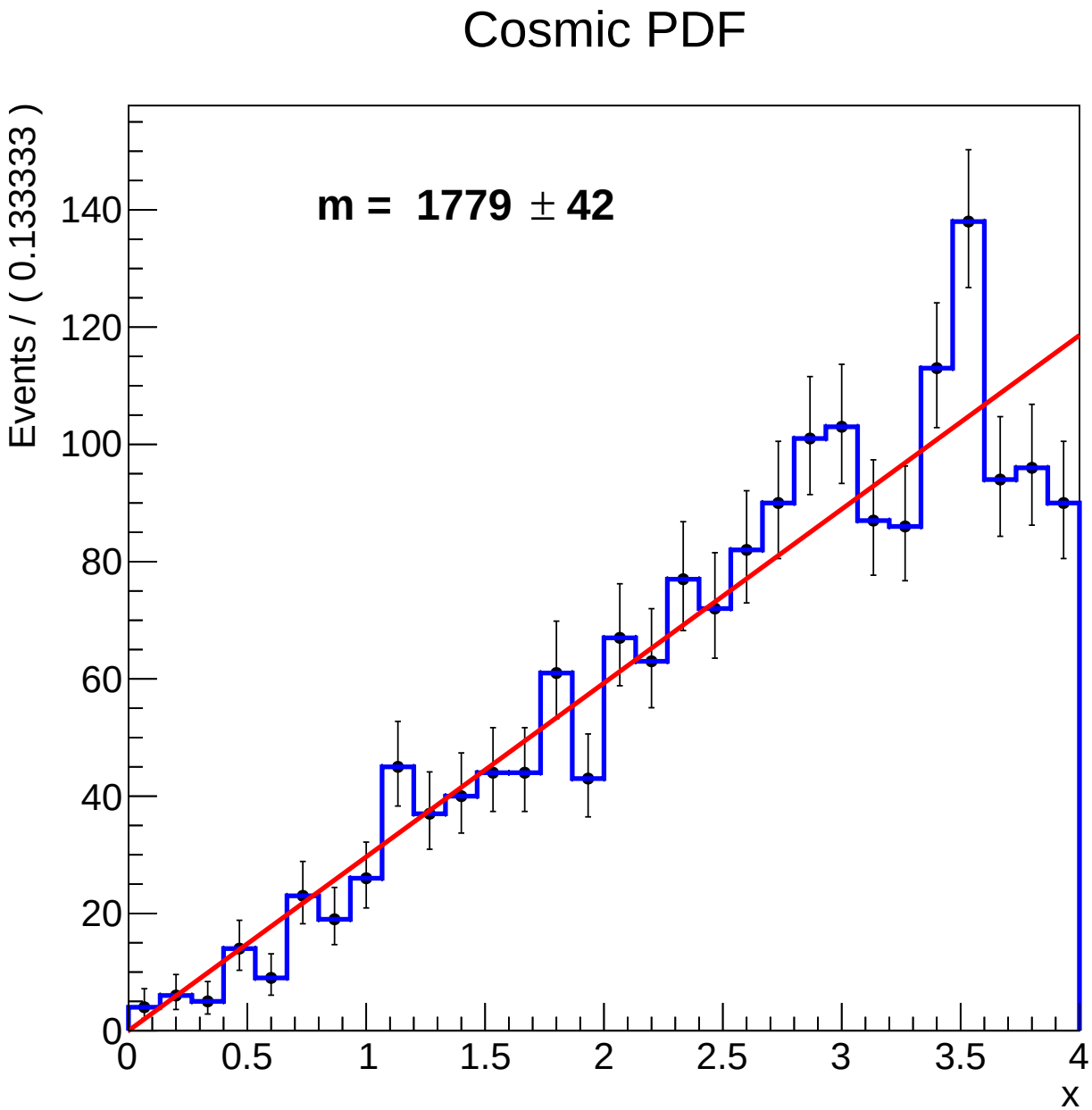
UWlosses

The microwave losses represent an almost pure anti-hydrogen sample of annihilation events due to residual gas inside the trap.

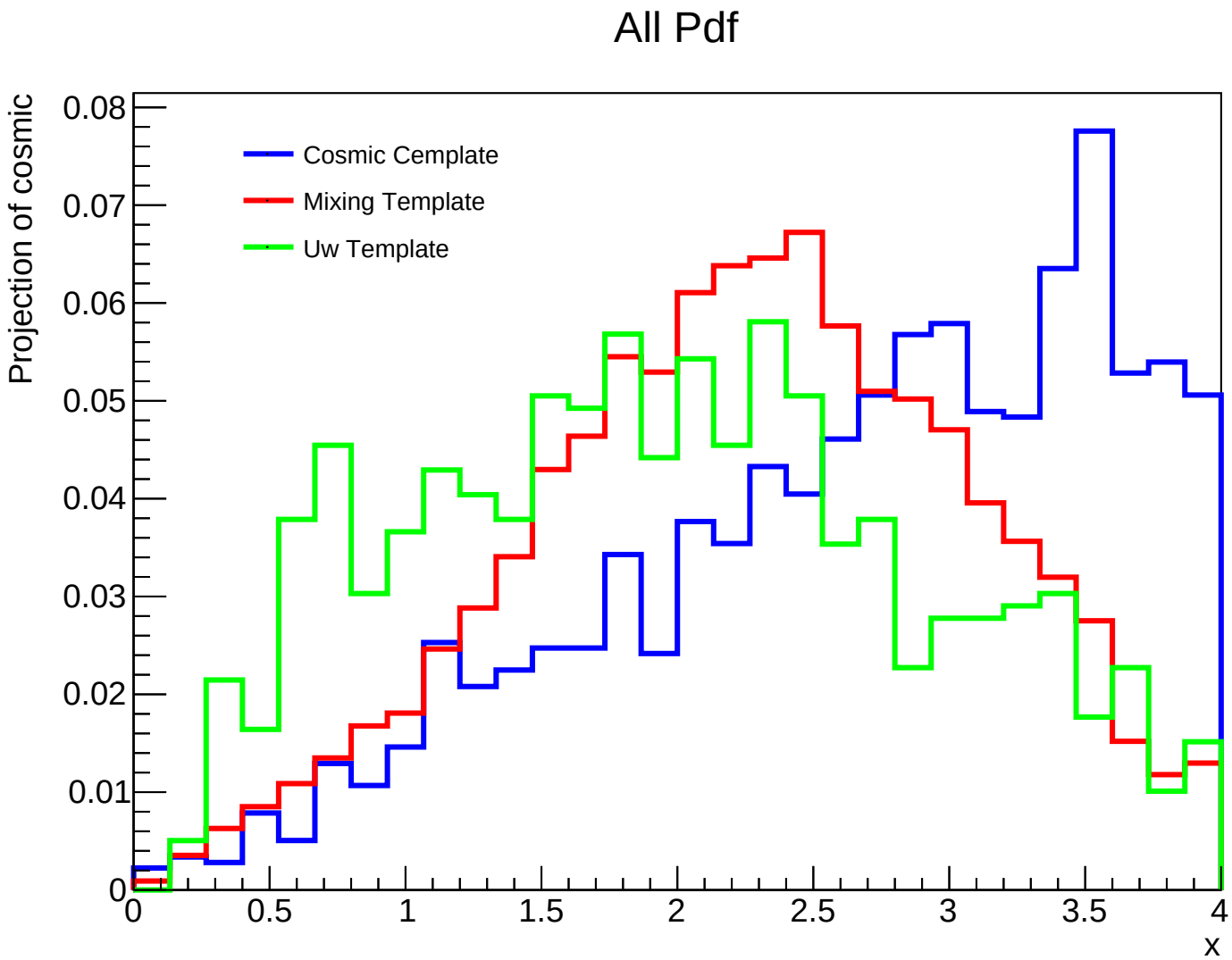


Cosmic

The cosmic distribution is obtained from dataset without anti-hydogren.



Pdfs normalized plotted together



Radial Density

The histogram in r variable doesn't account for the different area of the bin which is $2\pi r \cdot dr$. So it is useful to divide per $2\pi r$ to obtain the radial density of the events.

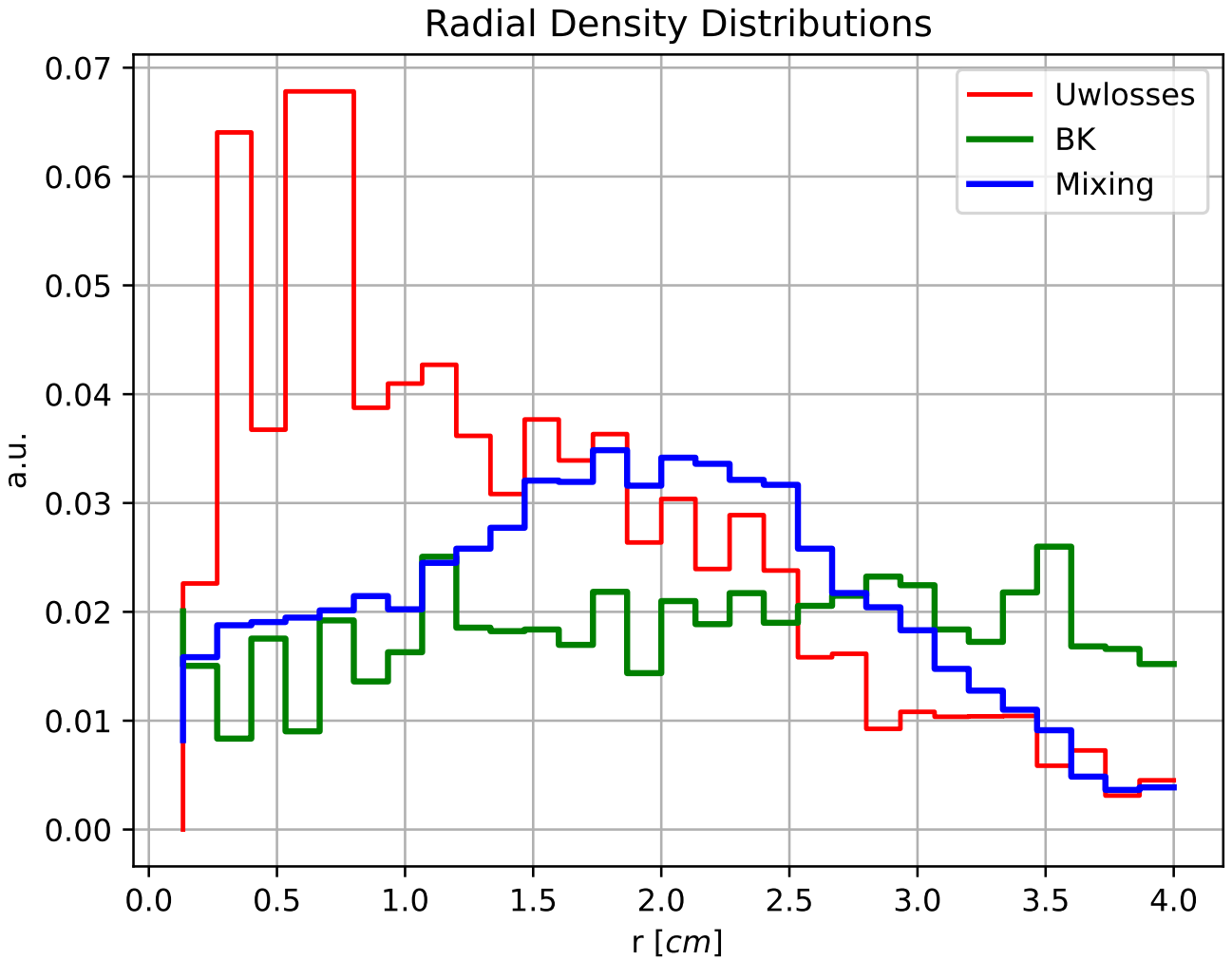


Figure: Radial density Pdf for f4 dataset

Toy simulation.

To study the accuracy of the algorithm to reconstruct the various parameter, we have developed a "toy" simulation tool. The model to generate the data is:

$$Pdf_{total} = a \cdot Gauss_{mix} + b \cdot Rayleigh + c \cdot linearModel_{cosmic} \tag{1}$$

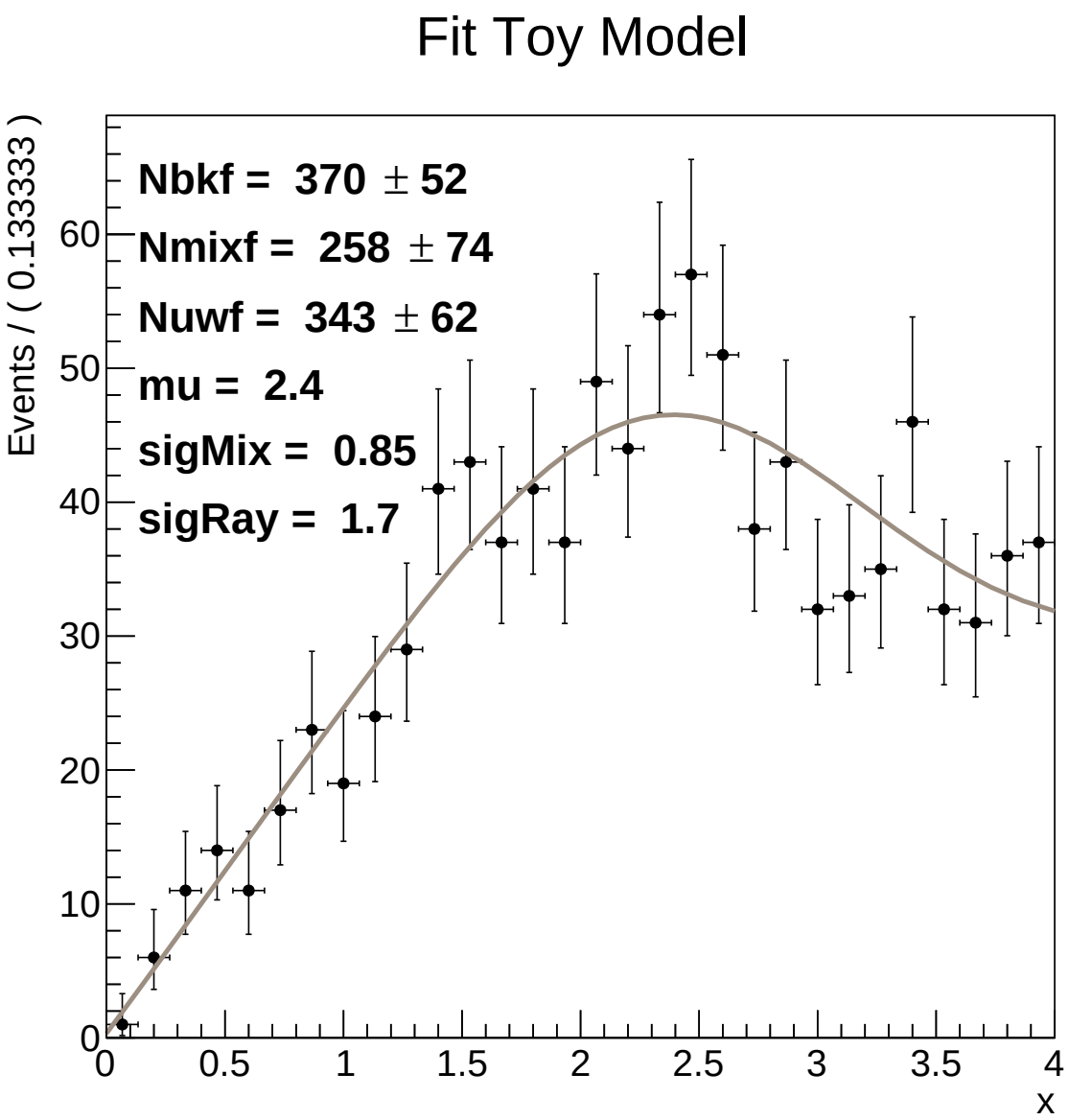
where a, b, c represent the "weights" of the various contributions to the Pdf used to generate the data. The number of annihilation is indicated as N_{sample}. Once the data are generated, they are fitted with the model:

$$Pdf_{fit} = Nfit_{mix} \cdot Gauss_{mix} + Nfit_{uw} \cdot Rayleigh + Nfit_{bk} \cdot linearModel_{cosmic} \tag{2}$$

The parameters of the fit are $Nfit_{mix}$, $Nfit_{uw}$ and $Nfit_{bk}$. The "true value" are defined as:

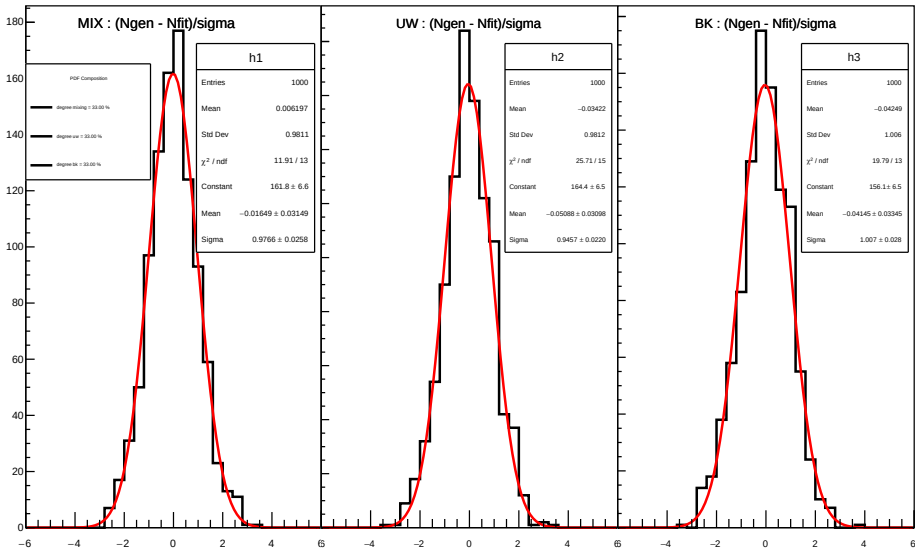
- $Ngen_{mix} = a \cdot N_{sample}$
- $Ngen_{uw} = b \cdot N_{sample}$
- $Ngen_{bk} = c \cdot N_{sample}$

Example of fit, Toy: $N_{sample} = 1000$, a = 33%, b = 33%, c = 33%



Toy: $N_{sample} = 1000$, a = 33%, b = 33%, c = 33%

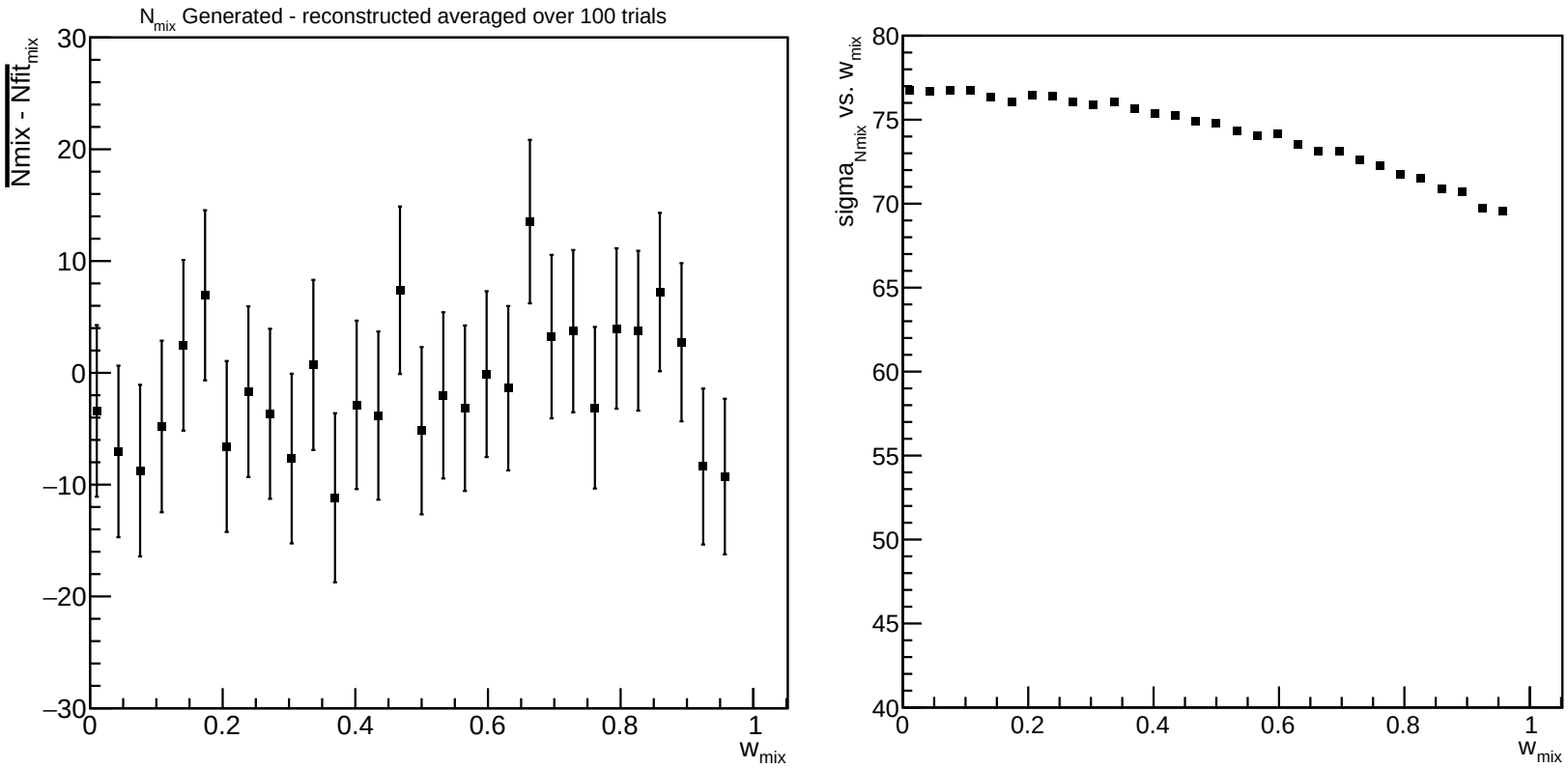
In this plot we have fixed the weight of each distribution to 33%, with $N_{sample} = 1000$ and $N_{trials} = 1000$. This first plot is made to ensure that the algorithm is able to reconstruct the parameters, and check the presence of a bias. The variable of the histograms are: $\frac{Ngen - Nfit}{\sigma_{fit}}$



The distribution are normal, the fit is behaving as expected.

weight variation *a* for mix.

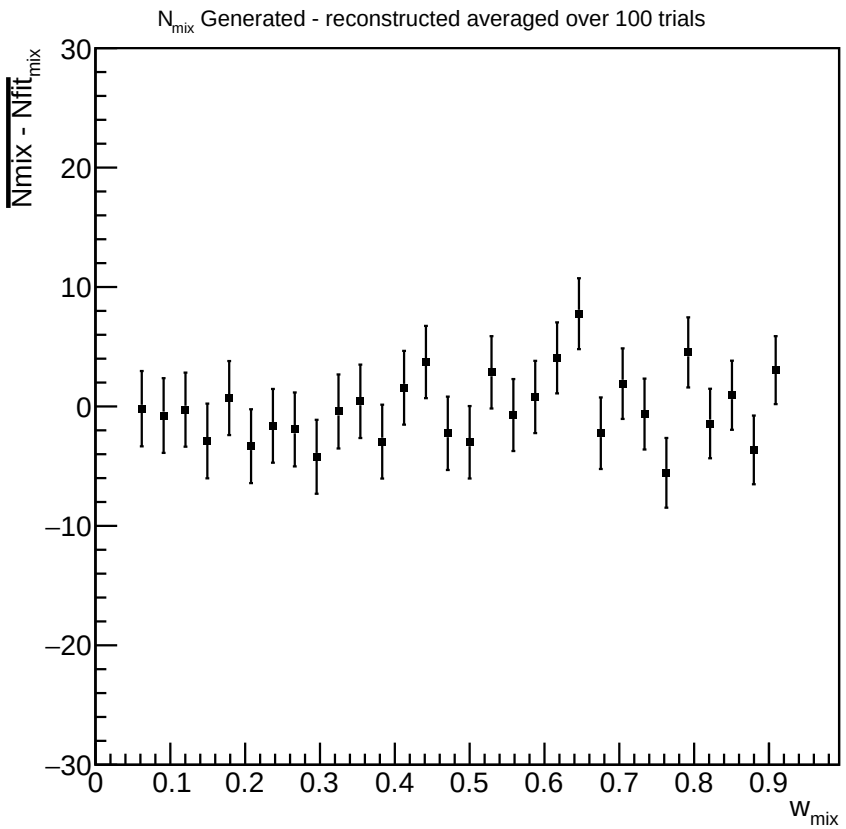
Now we study how or if the coefficients of the fit $Nfit_{mix}$, $Nfit_{uw}$ and $Nfit_{bk}$ vary with the increment of the weight a. At fixed $c = 10\%$, a is raised from 10% to 80% and b is decreased accordingly.

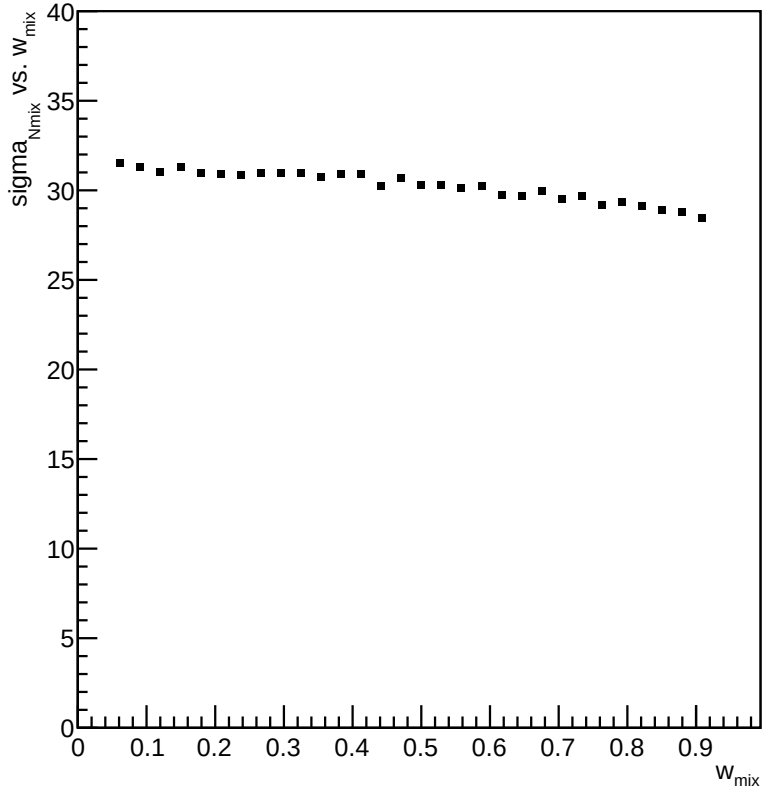


The number events is always $N_{sample} = 1000$. For each value of the weight a we iterate 100 times ($N_{trials} = 100$) to study the reconstructed coefficients with the variation of the weights.

$N = 165$.

Now we have done the same plot with $N = 165$, the same amount of data in `r68465_uw_exp_freq4.vertex.csv` after applying *cut1*. The value of c is fixed to reproduce the number of expected events from background ($c = 6\%$).

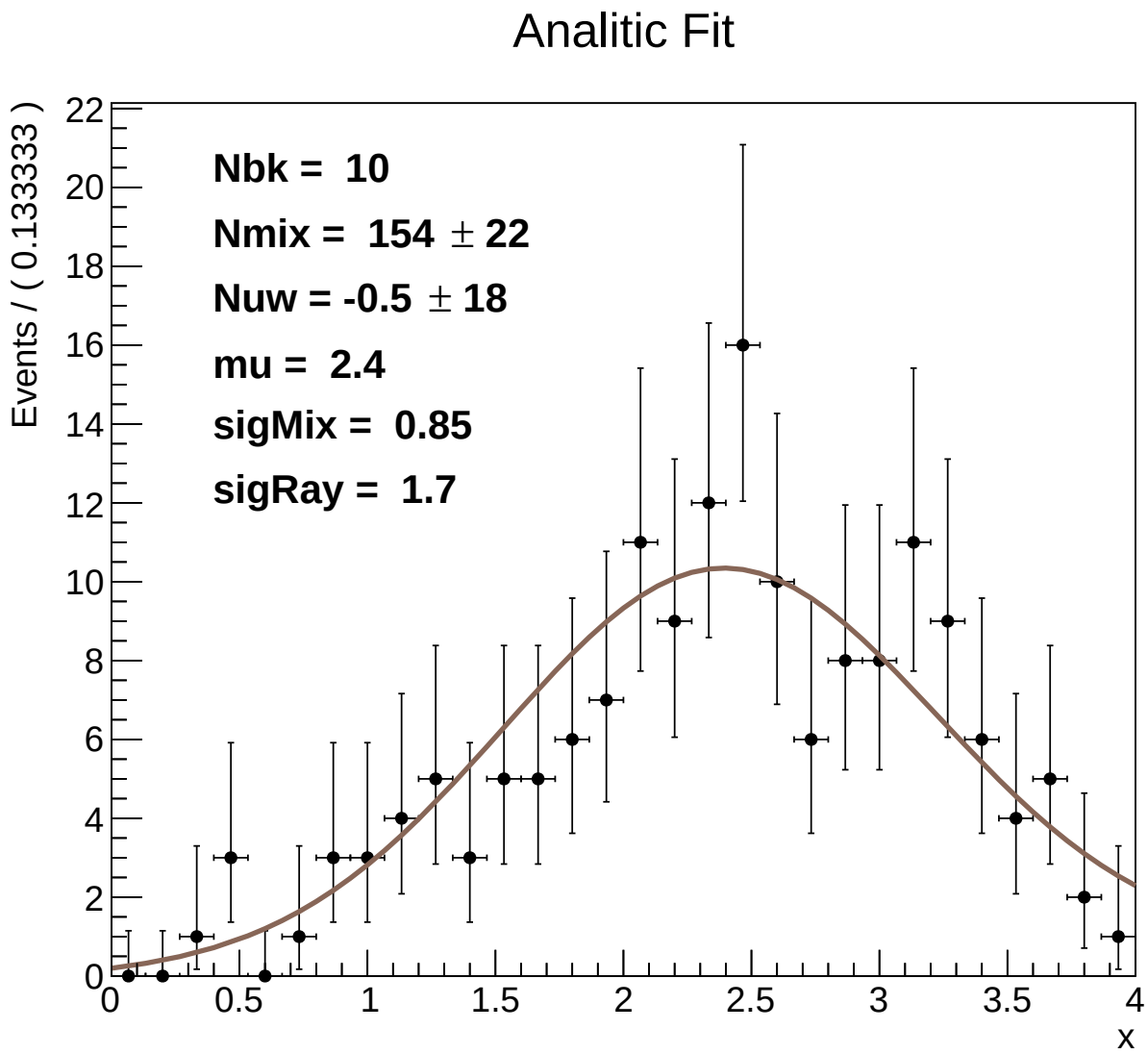




Fit to data.

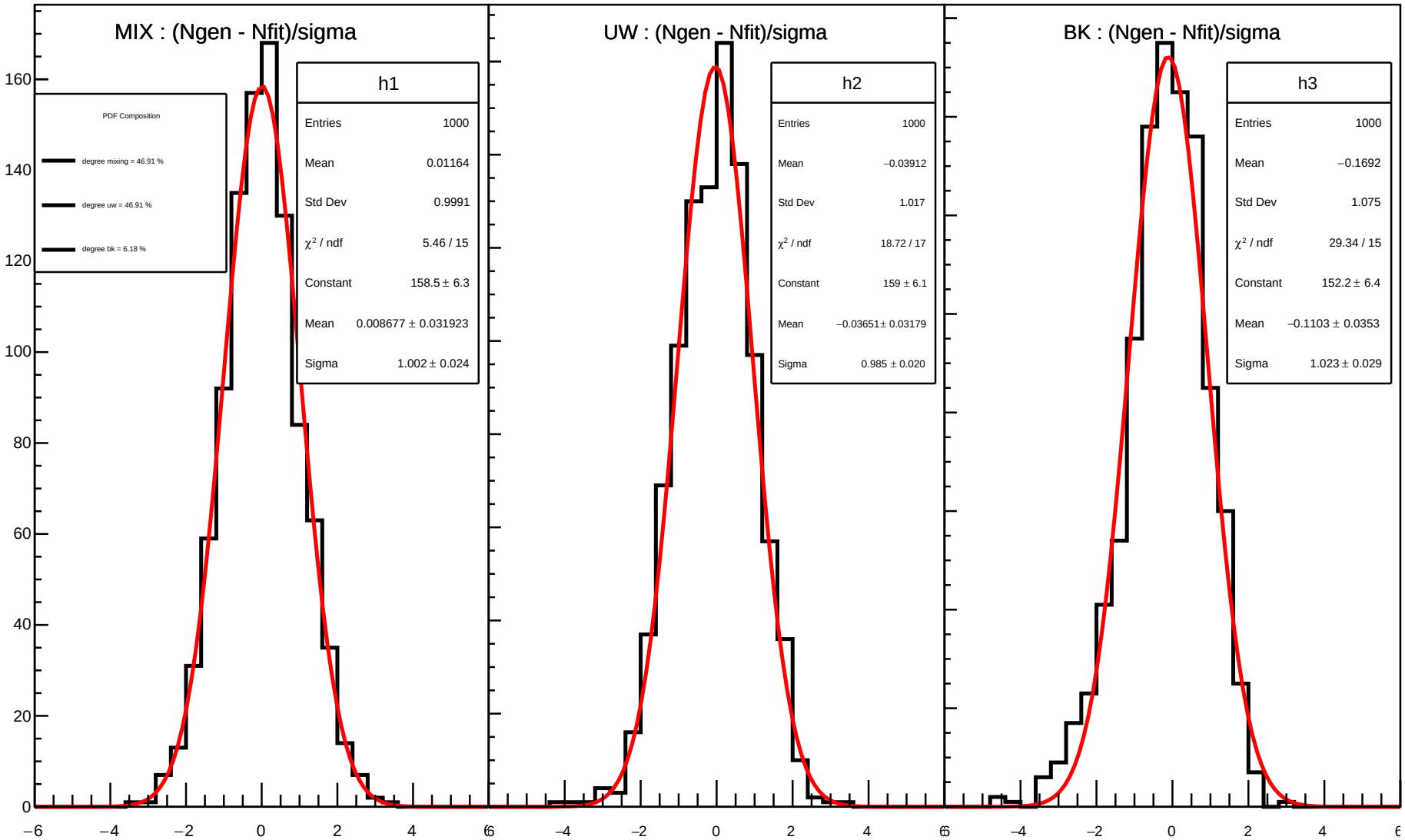
Pdf = Gaussian (Mixing) + Rayleigh (Uwlosses) + linear model (cosmic fixed).

Data taken from: `r68465_uw_exp_freq4.vertex.csv`



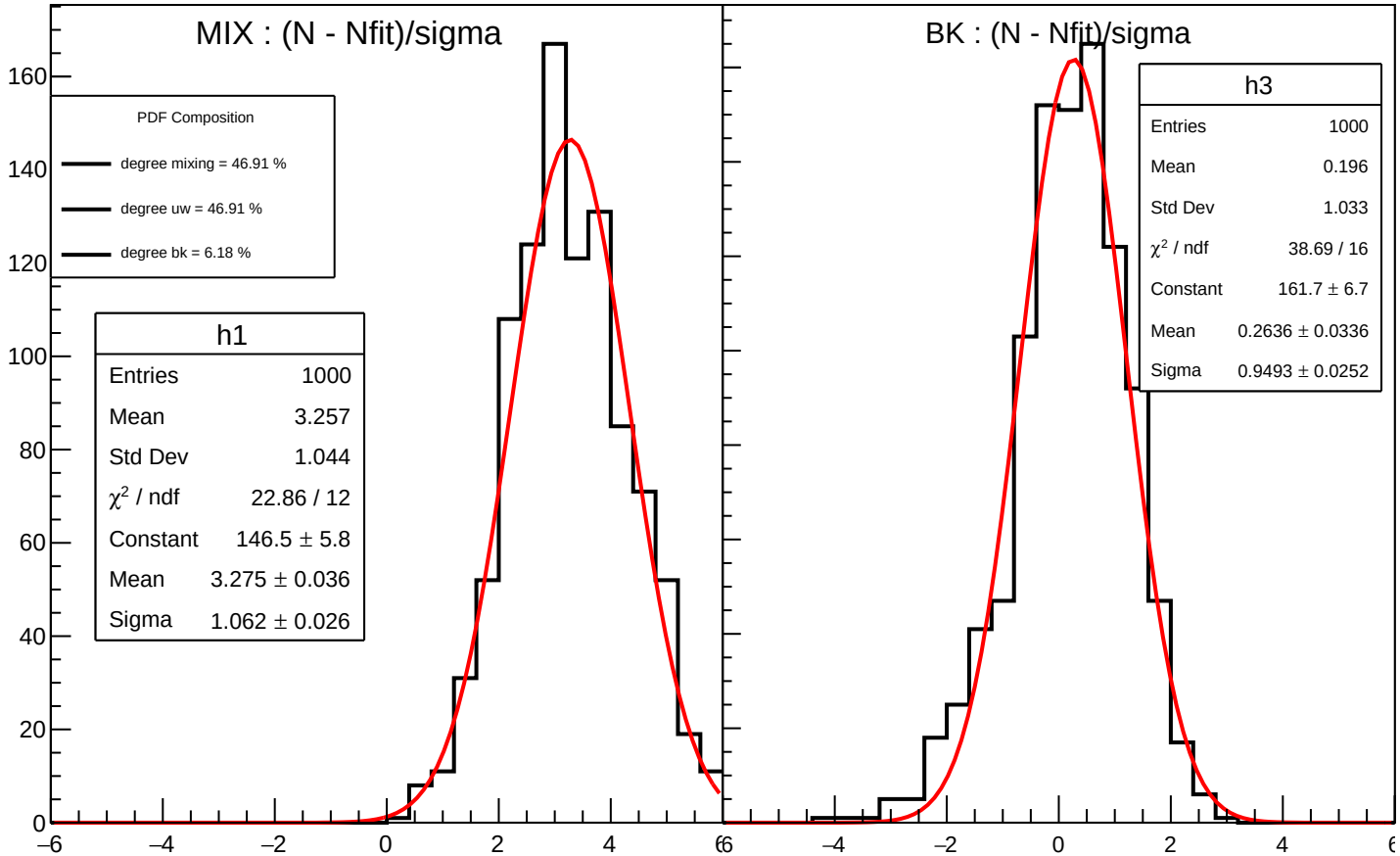
ADDITIONAL MATERIAL

$N_{mix} - N_{fit}$ for $a = 46\%$, $b = 46\%$, $c = 6\%$.



N_{uw} parameter of the fit model fixed

The Toy simulation is tested fixing the N_{uw} parameter of the fit model fixed. In the following plot the weight are $a = 46\%$, $b = 46\%$, $c = 6\%$, where c is fixed in such a way to reproduce the number of expected background events in `r68465_uw_exp_freq4.vertex.csv`, which correspond to 6% of the total events.



N_{uw} parameter of the fit model fixed

We study the bias $N_{mix} - N_{reconstructed}$ with the parameter N_{uw} of the fit model fixed at 0. For small value of w_{mix}, corresponding to small contribution of *Mixing* (and, conversely, a significant contribution of *Uwlosses* pdf) we observe a large bias.