Studying Annihilation Distributions

Adriano Del Vincio, Germano Bonomi,
Simone Stracka

University of Brescia, INFN Pisa

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Objective

A procedure to disantangle the contribution of annihilations of antihydrogen on the trap walls and on the residual gas has been developed and tested. It is based on a Maximum Likelihood fit of the radial distribution of the annihilations that has been tuned using an "ad-hoc" Monte Carlo simulation toy.

- The model/template for annihilations on the trap walls has been extracted from the 2-second mixing window.
- The model/template for annihilations of the residual gas has been obtained using the losses when antihydrogen is hold in the trap (microwaves - UW - losses).
- A model/template for the cosmic background is also used.

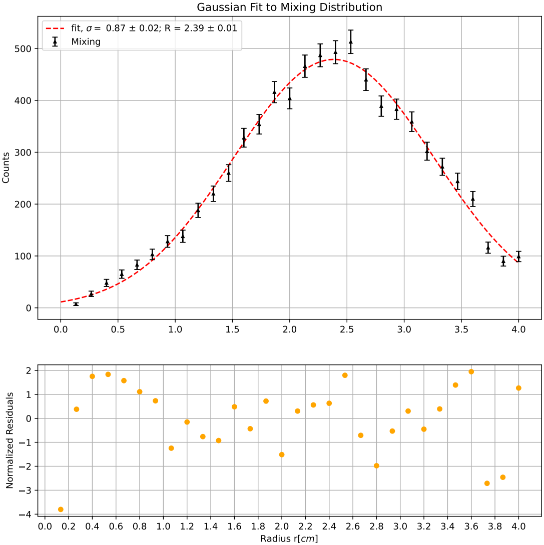
The PDFs used for the fit procedure and the data generation the data are listed below:

- PDF Mixing: the Normal distribution
- PDF Residual gas: 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, residual gas and cosmic data are fitted and the result are shown in the following slides.

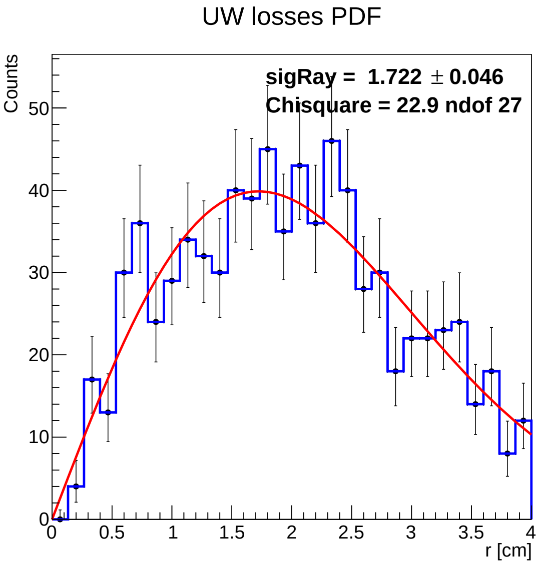
MIXING

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



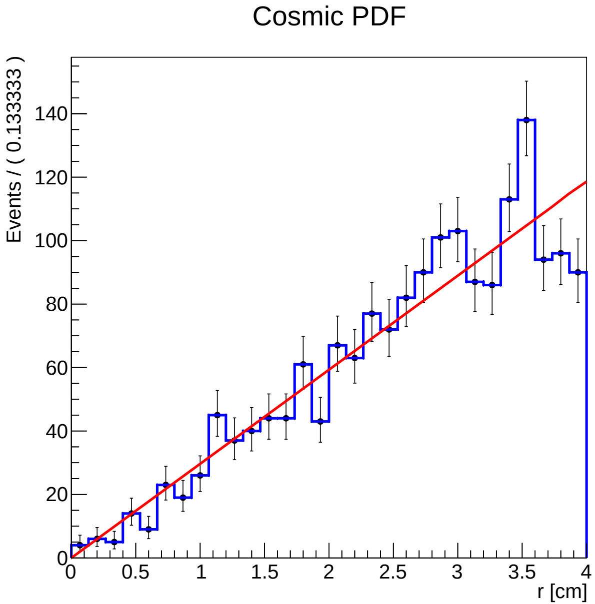
Residual Gas

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

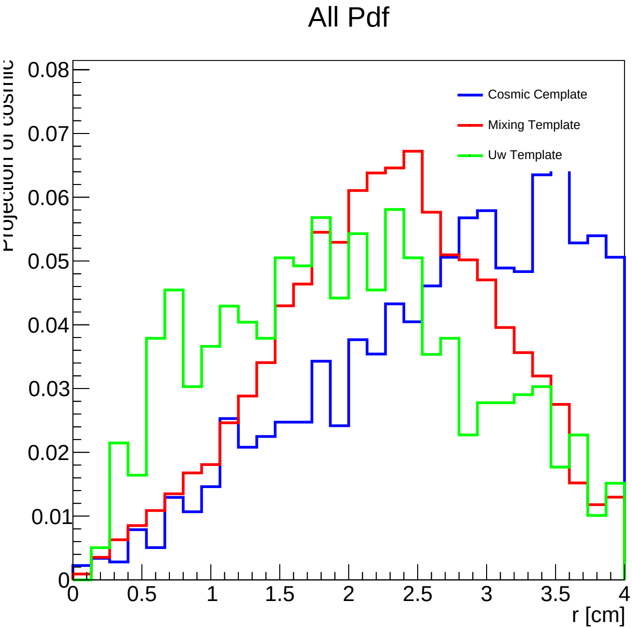


Cosmic

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



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.

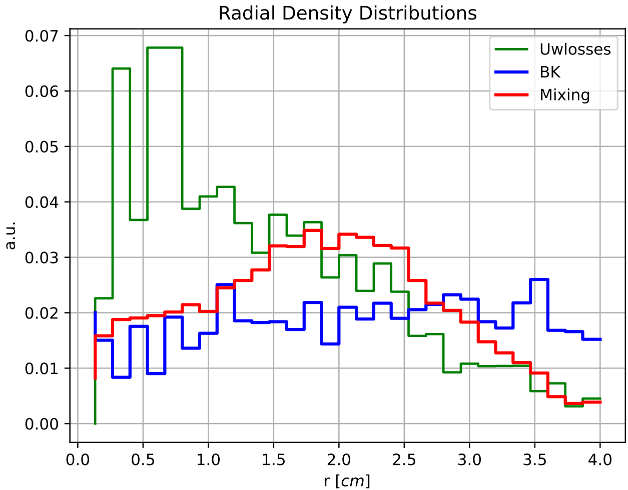


Figure: Radial density for `r68465_uw_exp_freq4.vertex.csv` dataset

Monte Carlo Simulation Toy

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:

$$F_{gen}(r) = N_{sample} \cdot (a \cdot PDF_{mix} + b \cdot PDF_{gas} + c \cdot PDF_{cosmic}) \tag{1}$$

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:

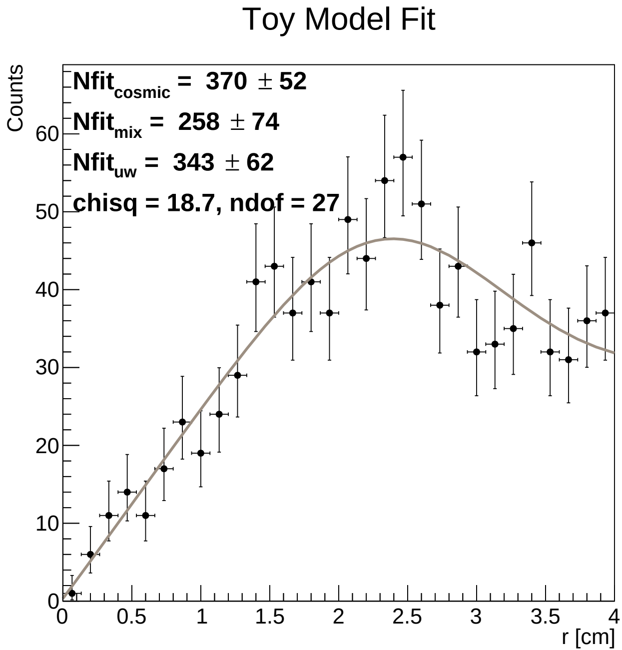
$$Nfit_{mix} \cdot PDF_{mix} + Nfit_{uw} \cdot PDF_{gas} + Nfit_{bk} \cdot PDF_{cosmic} \tag{2}$$

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

- $Ngen_{mix} = a \cdot N_{sample}$
- $Ngen_{gas} = b \cdot N_{sample}$
- $Ngen_{cosmic} = c \cdot N_{sample}$

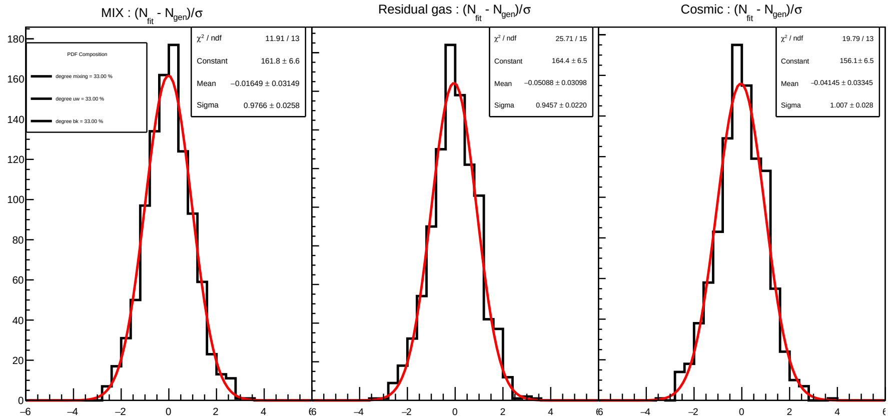
In generation $Ngen_{mix}$,$Ngen_{gas}$,$Ngen_{cosmic}$ are varied accordin to a Poissonian distribution.

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



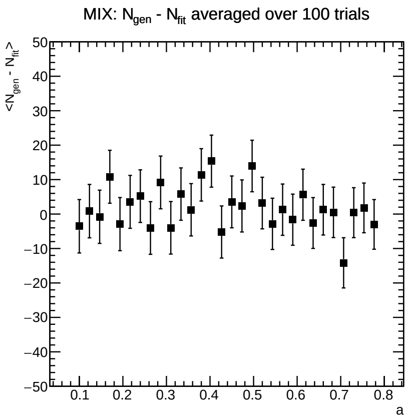
Toy: $N_{sample} = 1000$, a = 33%, b = 33%, c = 33%

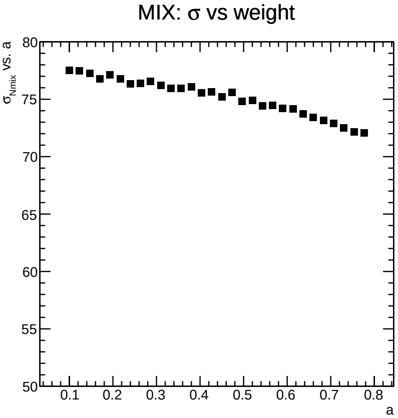
In this plot we have fixed the weight of each distribution to 33%, with $N_{sample} = 1000$ and $N_{trials} = 1000$, to ensure that the algorithm is able to reconstruct the parameters, and check the presence of a bias. The variable of the histograms are: $\dfrac{Nfit - Ngen}{\sigma_{fit}}$. The distributions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



weight variation a for mix.

Now we study how 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.

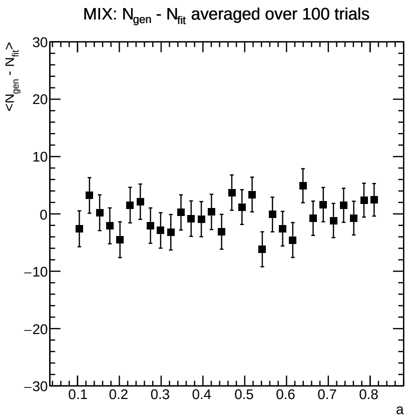


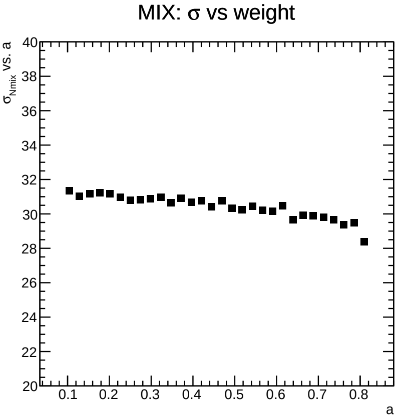


The number events is always $N_{sample} = 1000$. For each value of the weight a we iterate 100 times ($N_{trials} = 100$) to study the reconstructed coefficients with the variation of the weights.

$N_{sample} = 165$.

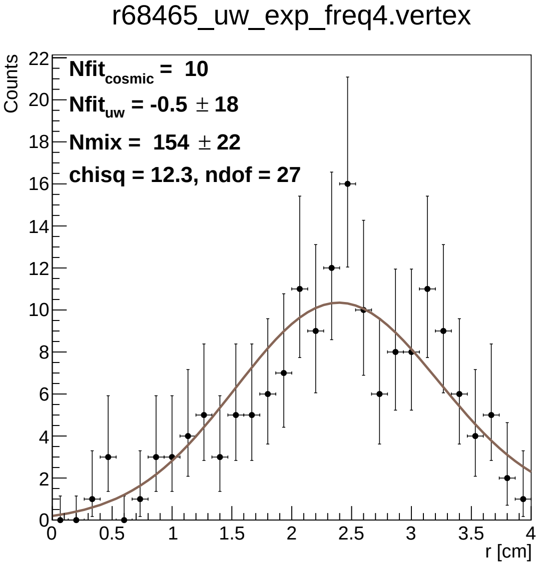
Now we have done the same plot with $N = 165$, the same amount of data in `r68465_uw_exp_freq4.vertex.csv` after applying *cut1*. The value of c is fixed to reproduce the number of expected events from background ($c = 6\%$).





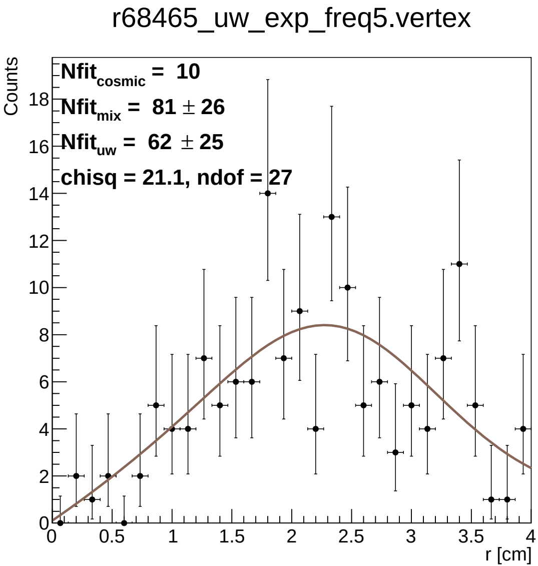
Fit to Data

PDF = Gaussian (Mixing) + Rayleigh (Residual gas) + linear model (cosmic fixed).
Data taken from: `r68465_uw_exp_freq4.vertex.csv`



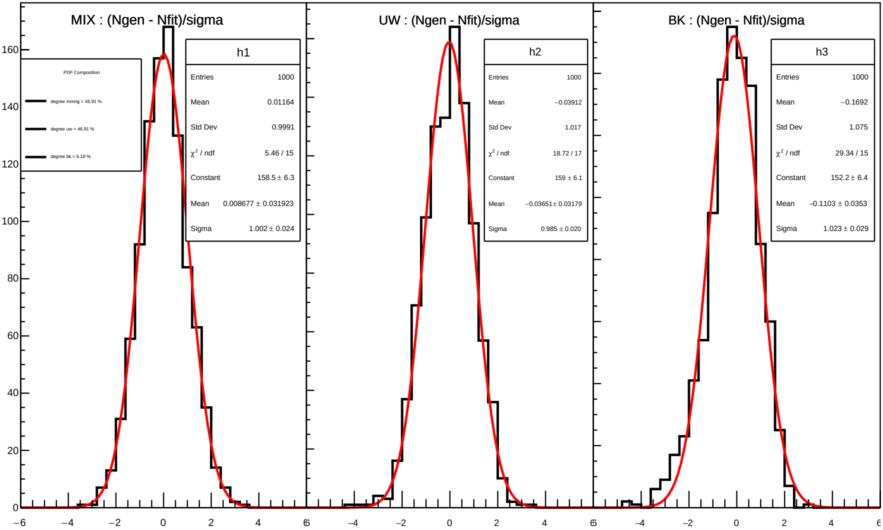
Fit to Data

PDF = Gaussian (Mixing) + Rayleigh (Residual gas) + linear model (cosmic fixed).
Data taken from: `r68465_uw_exp_freq5.vertex.csv`



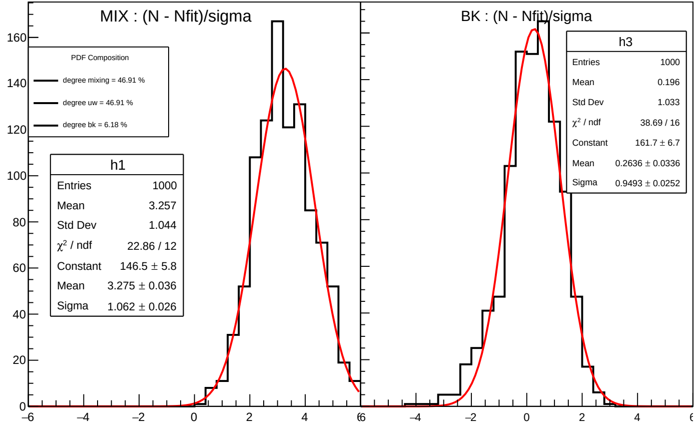
ADDITIONAL MATERIAL

$N_{mix} - N_{fit}$ 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 to 0. 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 dataset: `r68465_uw_exp_freq4.vertex.csv`. Considering the 200 seconds of time length of `r68465` we have fixed c to 6%, which corresponds to 10.2 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 to 0. For small value of w_{mix}, corresponding to small contribution of *Mixing* (and, conversely, a significant contribution of *Residual gas* PDF) we observe a large bias.