Toy Model For Hyperfine Measurement

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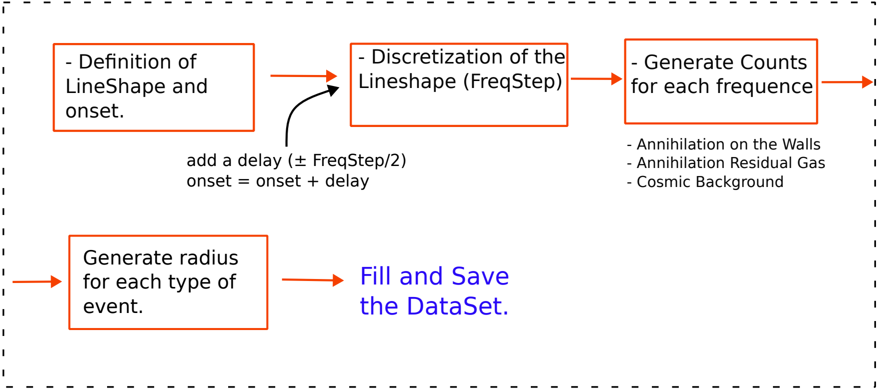
Scheme of the Simulation

Scheme of the Monte Carlo Toy for generating the events

Loop from 0 to Ntrials
Inner Loop: from 0 to Repetition



In this simulation, the data are created and analyzed using *RDataFrame* framework.

A brief introduction about the Monte Carlo

We have developed a Monte Carlo Toy that produces two `.root` dataset files. The variables are columns of values that are shown in the figure below:

Row	runNumber	random.ra	delay.del	frequence	type.type	radius.ra
0	0	0.4849736	2.4987087	-25	2	2.8792768
1	1	0.2899349	-1.685450	15	0	2.0739069
2	1	0.0197818	-1.685450	15	0	1.8959179
3	1	0.2412478	-1.685450	15	0	2.8919173
4	1	0.3846191	-1.685450	15	0	3.3842529
5	1	0.4549068	-1.685450	15	0	1.9130180
6	1	0.3739825	-1.685450	15	0	1.6047382

Figure: Structure of the dataset.

- *runNumber*: identifies which run the event belong to (from 0 to $Repetition - 1$)
- *random*: values uniform distributed from 0 to 1, can be used to randomize the selection or for sub-sampling in the data
- *delay*: store the onset delay
- *frequence*: the frequency of the event
- *type*: type of the event: 0 annihilation on the walls, 1 residual gas annihilation, 2 cosmic event
- *radius*: radius of the annihilation vertex.

A brief introduction about the Monte Carlo

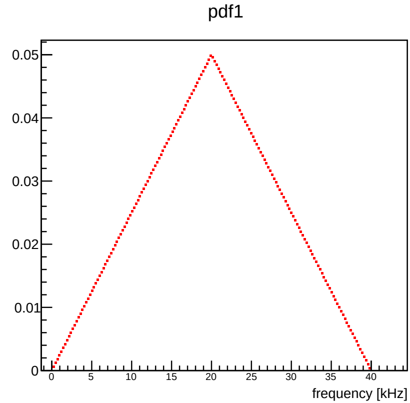
The Annihilation on the walls are generated as function of the frequency, using the two line-shapes of the transitions (c $\rightarrow$ b) and (d $\rightarrow$ a). The Annihilation on the residual gas and the cosmic background are generated uniformly on the frequency spectrum. All the parameters of the simulation are loaded from the `ToyConfiguration.txt` file. The parameters are chosen to reproduce the runs 4b.

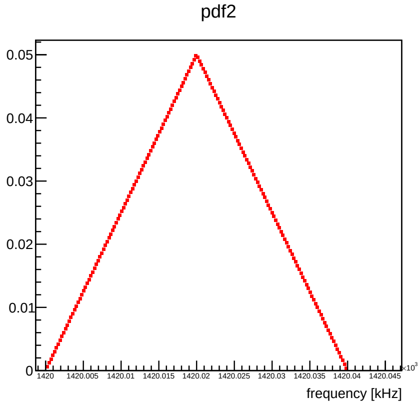
```
Nstack = 20
NHbar = 14
Repetition = 5
# cosmic rate is expressed in event/second
CosmicRate = 0.051028571
Efficiency = 1
pwall_cb = 1
pwall_ad = 1
C = 0.5
FrequencyStep = 5
TimeStep = 8
SweepStep = 24
# The following are in kHz units
x_cb_start = 0
x_cb_end = 40
x_cb_peak = 20
x_da_start = 1420000
x_da_peak = 1420020
x_da_end = 1420040
delay = 2.5
```

Figure: Parameters of the Toy.

Triangular Line-shape Pdfs

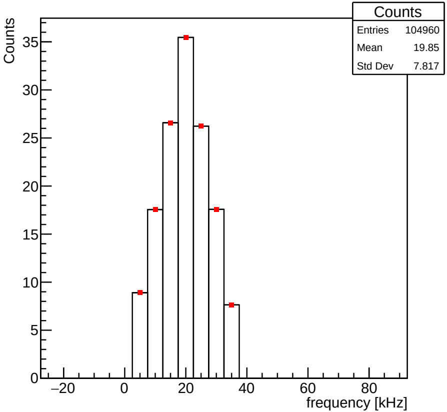
For this first use of the toy, we have chosen simple line-shapes, triangular with a symmetric rise and fall.

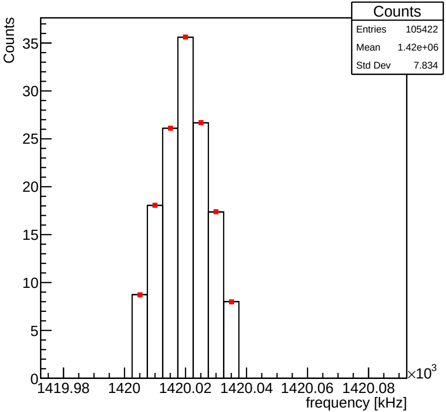




Triangular Line-shapes Simulation

We sample at the given frequency step of 5 kHz the Pdfs, to simulate the experimental line-shapes. We applied the onset finding algorithm to this distribution.



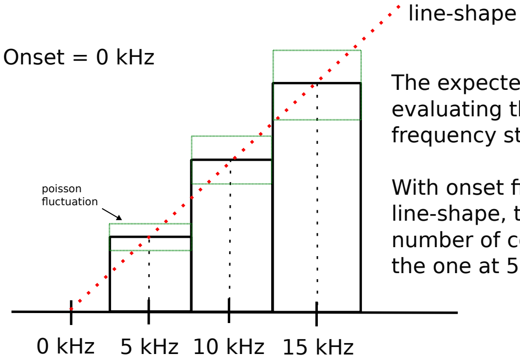


The onset is fixed ad $f = 0$ kHz. In this sample the cosmic background is set to zero.

A simple Onset finding Algorithm

The first algorithm that is tested is quite simple: **the onset is identified by the first bin with a content over a given threshold** ($> N\mu_{cosmic}$) [1]

Before showing the plot with the simulated data, it is useful to remind how this algorithm deals with the frequency step:



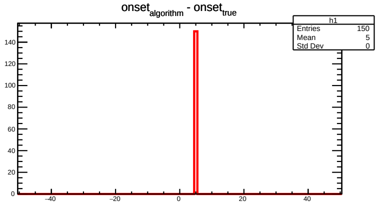
The expected bin content is given evaluating the lineShape at each frequency step (+ 5 kHz, +10kHz ...).

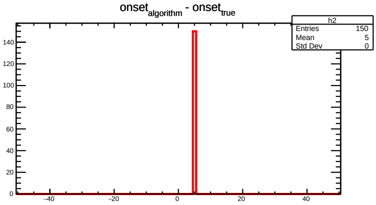
With onset fixed at 0, and a linear line-shape, the first bin with an expected number of counts different from 0 will be the one at 5 kHz (bias).

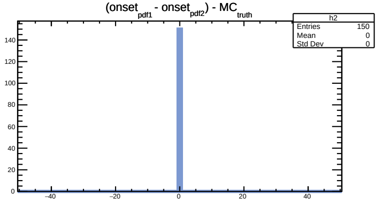
[1] Where the μ_{cosmic} is computed from the Poisson distribution of the cosmic counts expected per bin.

Consistency Check 1

We have tested the algorithm with a dataset without cosmic background and delay fixed to zero. The algorithm identifies the onset at frequency 5 kHz.

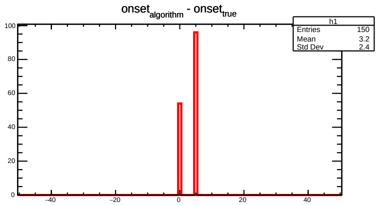


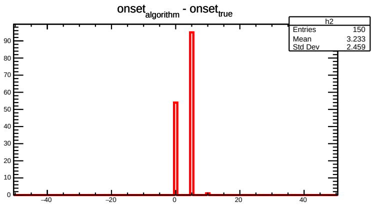


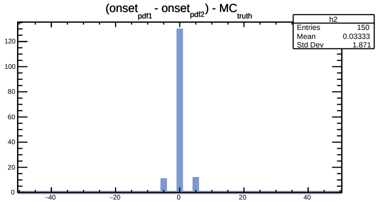


Consistency Check 2

We have tested the algorithm with a dataset without cosmic background. The delay is uniform distributed in $-2.5\,\mathrm{kHz}$ and $2.5\,\mathrm{kHz}$.

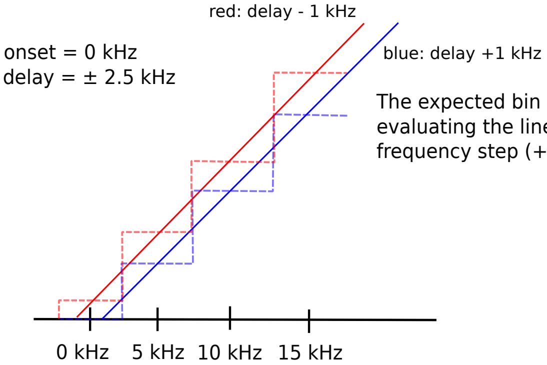






Consistency Check 2

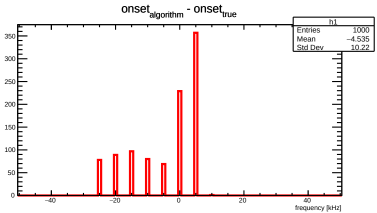
With the delay, two bins (*frequency* $= 0\,\text{kHz}$ and *frequency* $= 5\,\text{kHz}$) are populated.

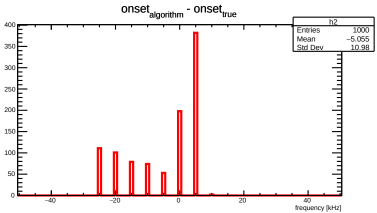


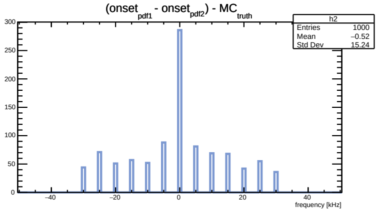
The expected bin content is given evaluating the lineShape at each frequency step (+ 5 kHz, +10kHz ...).

algorithm test: threshold $> 3\mu_{cosmic}$

In this case, we have applied the algorithm to simulated data with cosmic background (using a rate of $0.051\,\frac{event}{s}$, from passcut1). Each bin has an expected cosmic background of $dwelltime \cdot rate = 0.408$. The delay is uniform distributed in -2.5 kHz and 2.5 kHz.

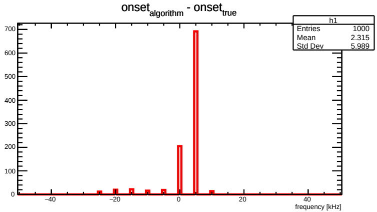


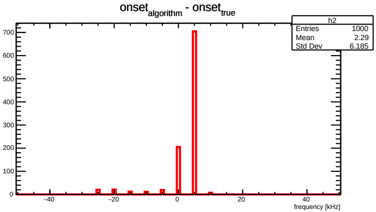


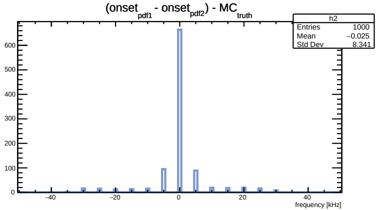


algorithm test: threshold $> 5\mu_{cosmic}$

In this case, we have applied the algorithm to simulated data with cosmic background (using a rate of $0.051\,\frac{event}{s}$, from passcut1). Each bin has an expected cosmic content of $dwelltime \cdot rate = 0.408$. The delay is uniform distributed in -2.5 kHz and 2.5 kHz.

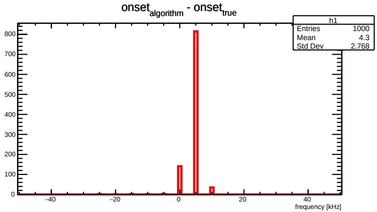


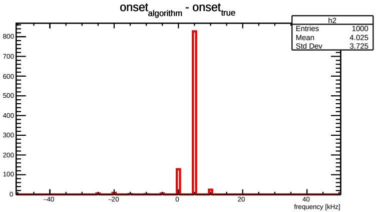


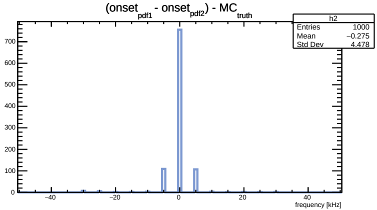


algorithm test: threshold $> 8\mu_{cosmic}$

In this case, we have applied the algorithm to simulated data with cosmic background (using a rate of $0.051\,\frac{event}{s}$, from passcut1). Each bin has an expected cosmic content of $dwelltime \cdot rate = 0.408$. The delay is uniform distributed in $-2.5\,\text{kHz}$ and $2.5\,\text{kHz}$.







Next step

- different line-shapes (e.g. quadratic rise, etc.)
- different onset-finding algorithm
- simulation of repetition/runs with Bfield drift.

Prob algorithm is triggered by the cosmic for threshold $> 3\mu_{cosmic}$ baseline over threshold is $P = 6.37\%$ (Poisson distribution, 1 - P(k=0) - P(k = 1)), calculation bring to 6.37%