Toy Model For Hyperfine Measurement

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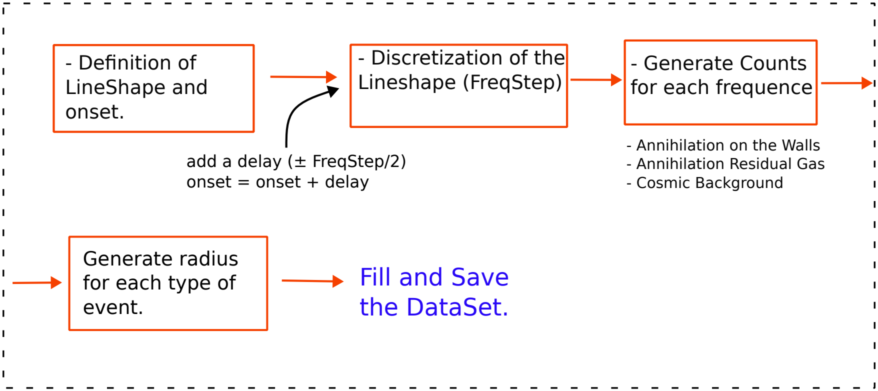
Scheme of the Simulation

Scheme of the Monte Carlo Toy for generating the events

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



- Definition of LineShape and onset.

- Discretization of the Lineshape (FreqStep)

add a delay (± FreqStep/2)
onset = onset + delay

- Generate Counts for each frequence

- Annihilation on the Walls
- Annihilation Residual Gas
- Cosmic Background

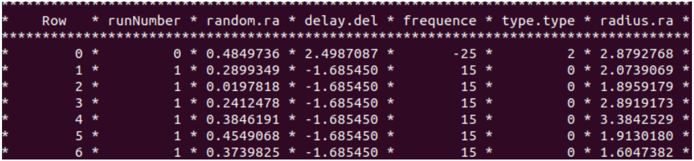
Generate radius for each type of event.

Fill and Save the DataSet.

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:



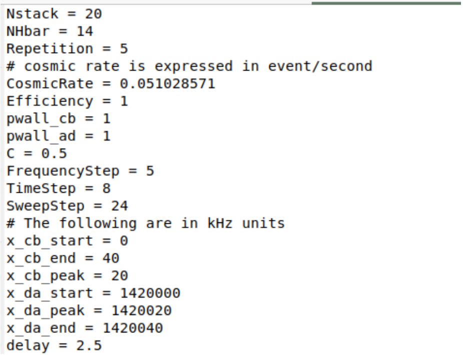
```
************************************************************************************
*    Row   * runNumber * random.ra * delay.del * frequence * type.type * radius.ra *
************************************************************************************
*        0 *         0 * 0.4849736 * 2.4987087 *       -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 → b) and (d → 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.

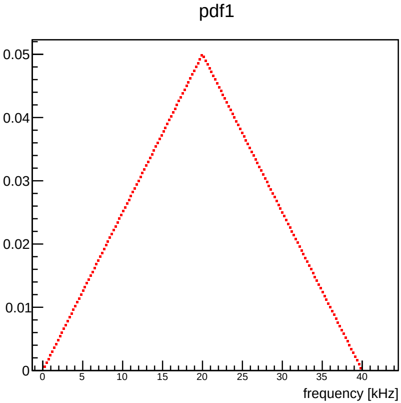


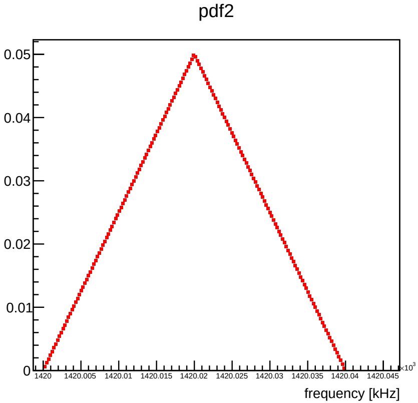
```
Nstack = 20
NHbar = 14
Repetition = 5
# cosmic rate is expressed in event/second
CosmicRate = 0.051028571
Efficiency = 1
pwall_cb = 1
pwall_ad = 1
C = 0.5
FrequencyStep = 5
TimeStep = 8
SweepStep = 24
# The following are in kHz units
x_cb_start = 0
x_cb_end = 40
x_cb_peak = 20
x_da_start = 1420000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

Figure: Parameters of the Toy.

Triangular Line-shape Pdfs

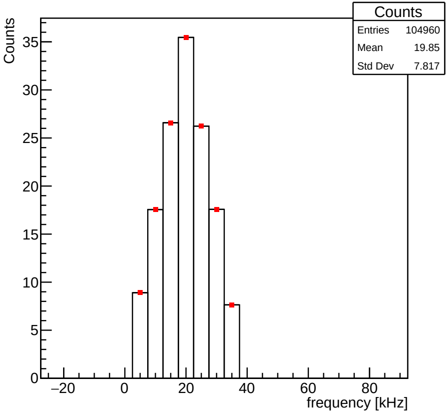
For this first use of the toy, we have chosen simple line-shapes, triangular with a symmetric rise and fall.

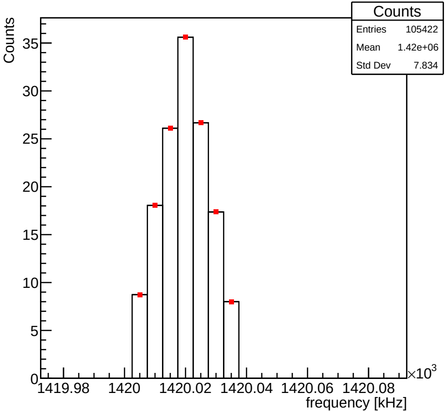




Triangular Line-shapes Simulation

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.



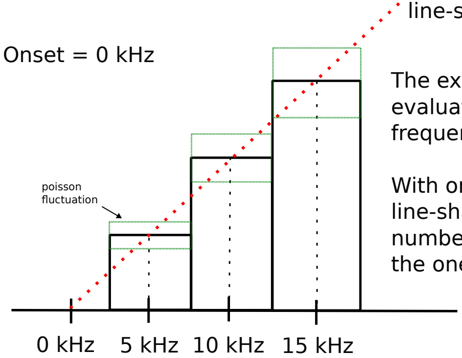


The onset is fixed ad $f = 0$ kHz. In this sample the cosmic background is set to zero.

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:



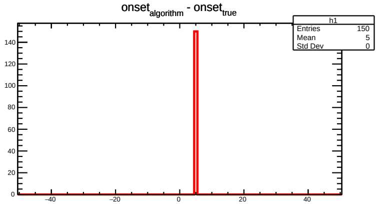
The expected bin content is given evaluating the lineShape at each frequency step (+ 5 kHz, +10kHz ...).

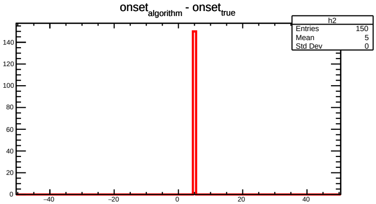
With onset fixed at 0, and a linear line-shape, the first bin with an expected number of counts different from 0 will be the one at 5 kHz (bias).

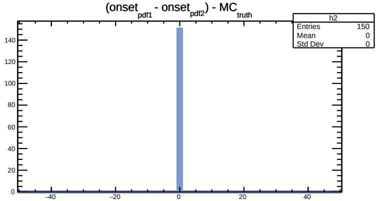
[1] Where the μ_{cosmic} is computed from the Poisson distribution of the cosmic counts expected per bin.

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.

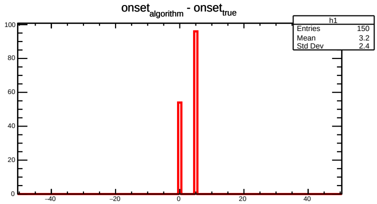




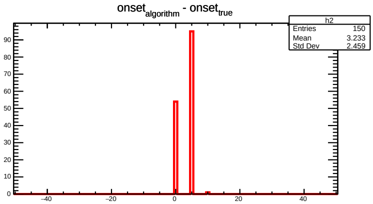


Consistency Check 2

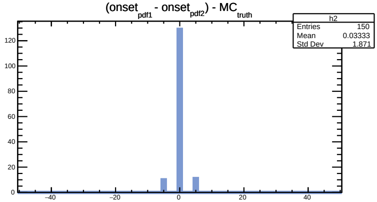
We have tested the algorithm with a dataset without cosmic background. The delay is uniform distributed in $-2.5\,\text{kHz}$ and $2.5\,\text{kHz}$.



$\text{onset}_{\text{algorithm}}$ - $\text{onset}_{\text{true}}$



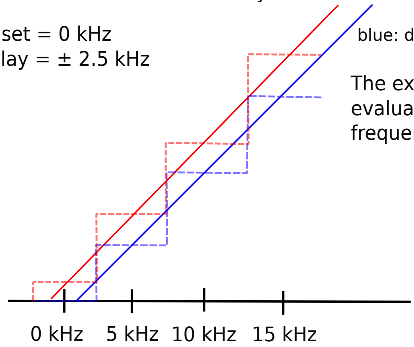
$\text{onset}_{\text{algorithm}}$ - $\text{onset}_{\text{true}}$



$(\text{onset}_{\text{pdf1}}$ - $\text{onset}_{\text{pdf2}})$ - MC_{truth}

Consistency Check 2

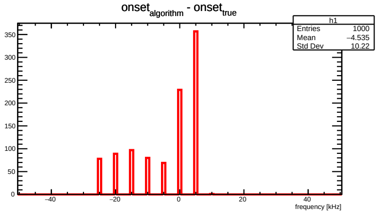
With the delay, two bins (*frequency* = 0 kHz and *frequency* = 5 kHz) are populated.

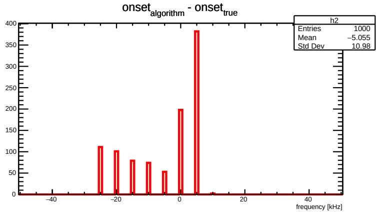


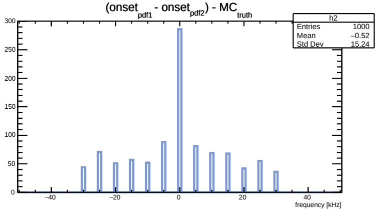
The expected bin content is given evaluating the lineShape at each frequency step (+ 5 kHz, +10kHz ...).

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 $-2.5\,\text{kHz}$ and $2.5\,\text{kHz}$.

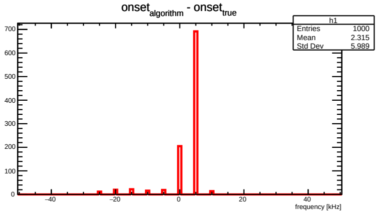




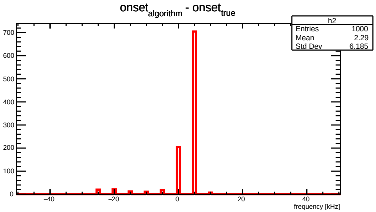


algorithm test: threshold $> 5\mu_{cosmic}$

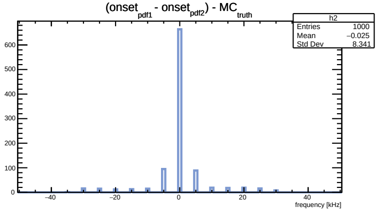
In this case, we have applied the algorithm to simulated data with cosmic background (using a rate of $0.051\,\frac{event}{s}$, from passcut1). Each bin has an expected cosmic content of $dwelltime \cdot rate = 0.408$. The delay is uniform distributed in -2.5 kHz and 2.5 kHz.



$onset_{algorithm}$ - $onset_{true}$



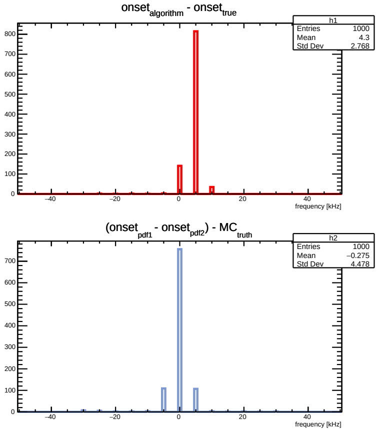
$onset_{algorithm}$ - $onset_{true}$



$(onset_{pdf1}$ - $onset_{pdf2})$ - MC_{truth}

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.

Improvements of the week (24/11/30 - 24/12/07)

- Implemented the onset-finding algorithm of 2017 ($\textit{first} > 0, \textit{second} > 1$)
- Simulation with a lineShape following the `run 69373` (lineShape with high statistics).
- Implementation and test of different onset finding algorithms.

Fit to the data of run 69373

The lineShape is fitted using a Cruijff function, which takes into account the asymmetry of the left-right tails, $(model = N \cdot exp(\frac{-(x-x_0)^2}{2\sigma_{0,1}+k_{0,1}(x-x_0)^2}))$

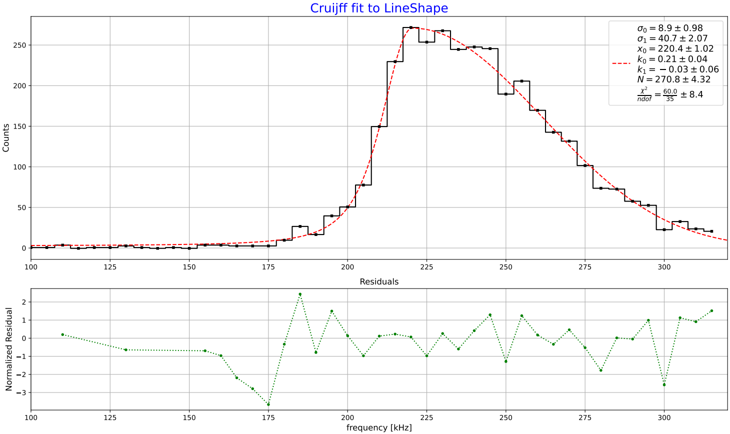


Figure: On top plot, the black line represents data and the red line the fit with the Cruijff function.

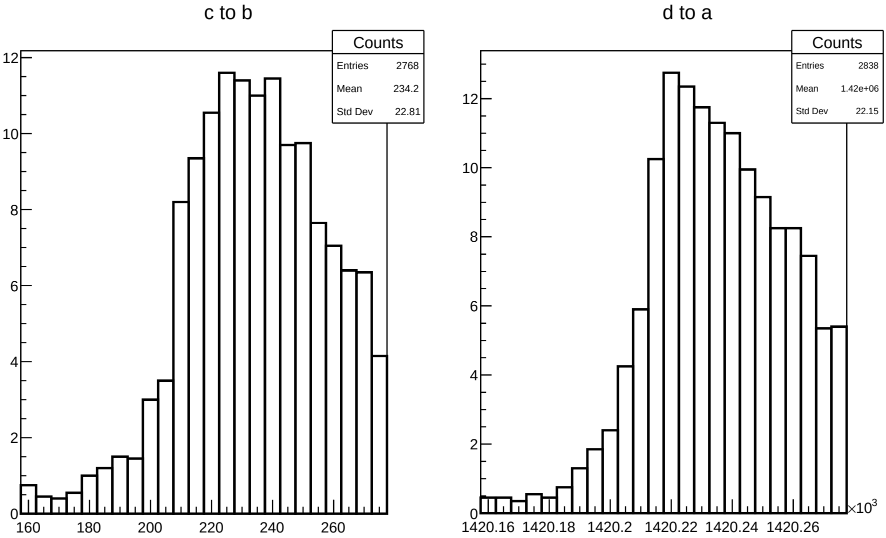
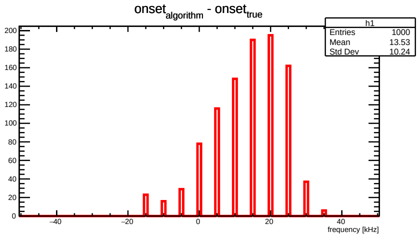
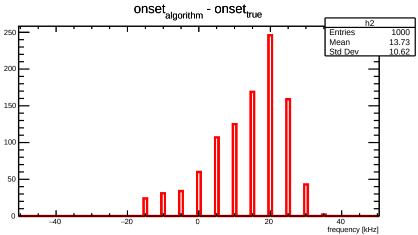
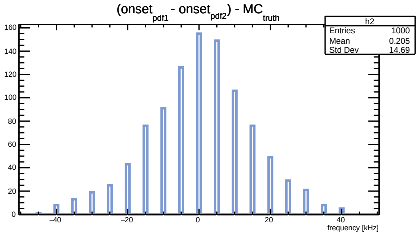


Figure: Histogram of the generated lineshape for 20 run. The Lineshape is scaled by a factor of 20.

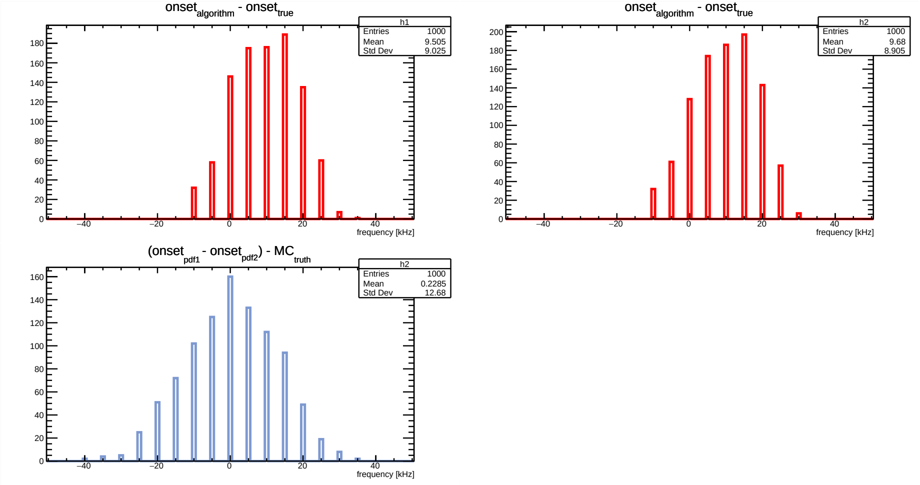
test 2017 algorithm







test 2017 algorithm (reversed)


onset_algorithm - onset_true
h1
Entries 1000
Mean 9.505
Std Dev 9.025
frequency [kHz]
onset_algorithm - onset_true
h2
Entries 1000
Mean 9.68
Std Dev 8.905
frequency [kHz]
(onset_pdf1 - onset_pdf2) - MC_truth
h2
Entries 1000
Mean 0.2285
Std Dev 12.68
frequency [kHz]