1 Rigorous test of Tanya Risemans maximum entropy analysis package

Wednesday, March 7, 2001

I am starting with a rigorous test of Tanya Risemans maximum entropy analysis package, which is installed on

`'/afs/psi.ch/project/lem/max_entropy'`

1.1 Step – matlab

I am producing synthetic data with matlab (program: `synt_his_wkm.m` in `'/afs/psi.ch/users/s/suter_a/matlab'`). It produces the `WKM` output format, which can directly be read by `max0103`.

The general formula for the input signal is:

$$s_i(t) = N_0 \exp(-t/\tau_\mu)\,[1 + A_i f_i(t)] + B$$

where the index i labels the corresponding detector. In the LEμSR experiment there are maximal 4 detectors. $\tau_\mu = 2.2\mu$s. The gyromagnetic ratio of the Muon is $\gamma_\mu = 2\pi \cdot 135.697$MHz/T.

1.1.1 pure cosine

The signal parameters are as following:

N_0	10^3
A_i	0.3
$f_i(t)$	$\cos(\omega t + \phi_i)$
ω	2Mc/s $\Rightarrow$ 23.457G
ϕ_i	$(0, -\pi/2, \pi, \pi/2)$
B	0
binning	10^4 bins, 1 ns raster

The following parameters were entered:

Use time binning convolution	no
Background signal asymmetry	0.0
Remove group	no
Time range and binning size	$[0, 10, 0.001]$ μs
Start variable binning	20 μs
Power of generalized gaussian for var binning	2
Decay time of gen gaussian for var binning (us)	100
Sigma apodization time (us)	10^{14}
Sigma looseness factor	1
Test criterion (precision)	0.001
Do you want to keep the phases fixed	yes
Power for number of points	2^{15}
Min and max fields (in Telsa)	$[0, 0.005]$
Default level twiddle factor	1
Fit using sqrt(theory) as the errors?	yes

The following error message was produced:

```
Bad! Chi^2=  1.3872683 is NOT 1 within tolerance of 0.00499999989
```

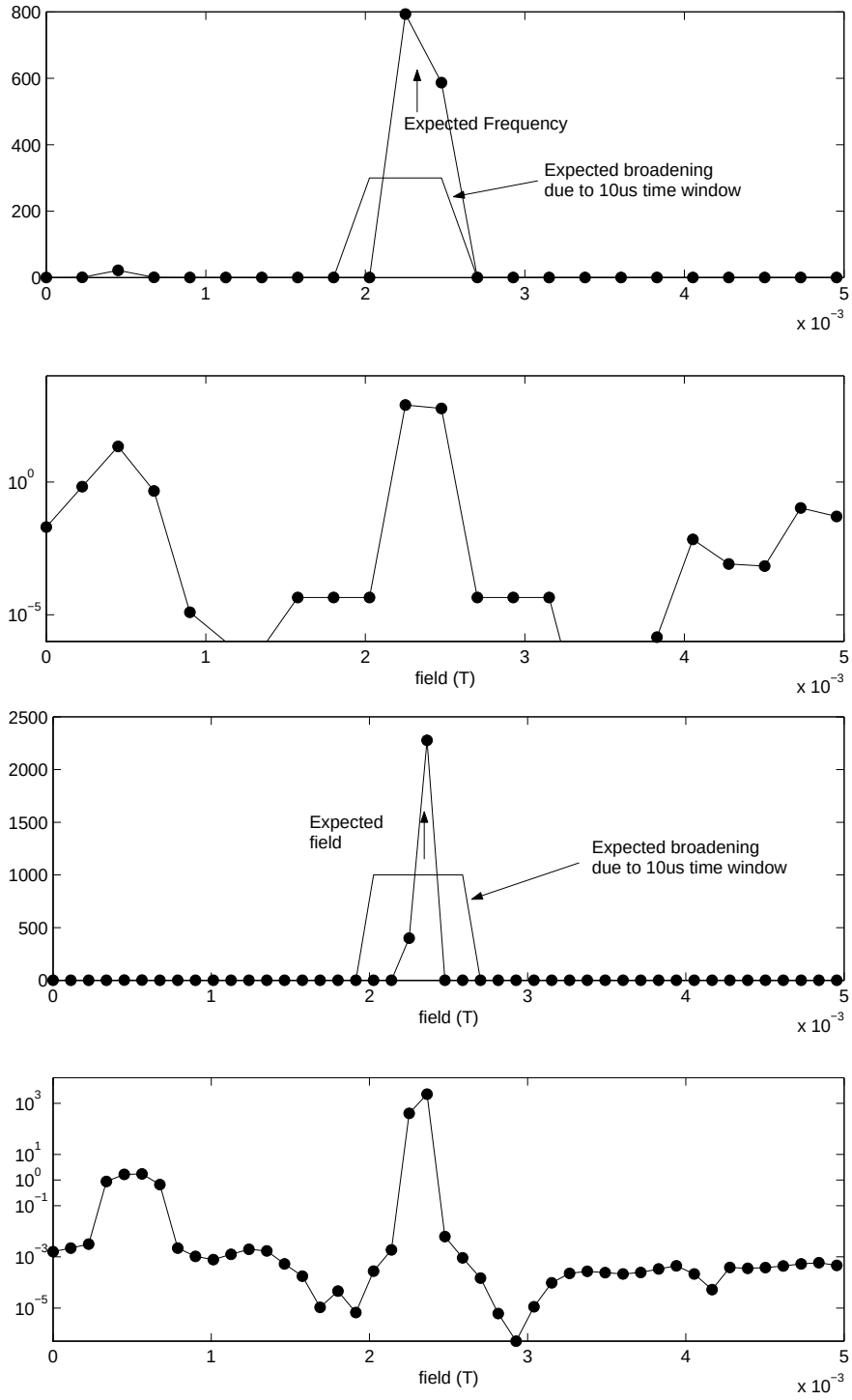

Figure 1: Result for pure cosine input. Also shown expected broadening due to finite observation window of 10 μs and expected peak field of 23.457 G. Top two: Binning 2^{15}. Bottom two: Binning 2^{16}

Use time binning convolution	no
Background signal asymmetry	0.0
Remove group	no
Time range and binning size	$[0, 10, 0.001]$ μs
Start variable binning	20 μs
Power of generalized gaussian for var binning	2
Decay time of gen gaussian for var binning (us)	100
Sigma apodization time (us)	10^{14}
Sigma looseness factor	1
Test criterion (precision)	0.001
Do you want to keep the phases fixed	yes
Power for number of points	2^{16}
Min and max fields (in Telsa)	$[0, 0.005]$
Default level twiddle factor	1
Fit using sqrt(theory) as the errors?	yes

No error message this time.

1.1.2 Two cosine close in frequency

The signal parameters are as following:

N_0	10^3
A_i	0.3
$f_i(t)$	$0.7\cos(\omega t + \phi_i) + 0.3\cos(1.3\omega t + \phi_i + e/\sqrt{7})$
ω	2Mc/s $\Rightarrow$ 23.457G
ϕ_i	$(0, -\pi/2, \pi, \pi/2)$
B	0
binning	10^4 bins, 1 ns raster

The following parameters were entered:

Use time binning convolution	no
Background signal asymmetry	0.0
Remove group	no
Time range and binning size	$[0, 10, 0.001]$ μs
Start variable binning	20 μs
Power of generalized gaussian for var binning	2
Decay time of gen gaussian for var binning (us)	100
Sigma apodization time (us)	10^{14}
Sigma looseness factor	1
Test criterion (precision)	0.001
Do you want to keep the phases fixed	yes
Power for number of points	2^{15}
Min and max fields (in Telsa)	$[0, 0.005]$
Default level twiddle factor	1
Fit using sqrt(theory) as the errors?	yes

1.1.3 sin(x)/x test

The signal parameters are as following:

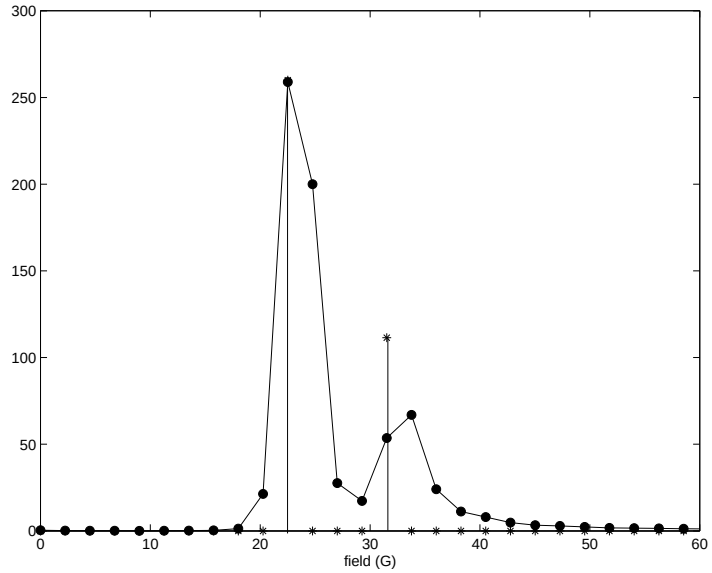

Figure 2: Two cosine close in field. Bullets: Result from `max0103`. Stars: Theoretical signal. Theoretical expected ratio between the amplitudes is $3/7 = 0.429$, whereas the integrated peak amplitude from the output of `max0103` gives 0.395, which is not too bad.

N_0	10^3
A_i	0.3
$f_i(t)$	$\sin(\omega t + \phi_i)/t$
ω	$2\text{Mc/s} \Rightarrow 23.457\text{G}$
ϕ_i	$(0, -\pi/2, \pi, \pi/2)$
B	0
binning	10^4 bins, 1 ns raster

The following parameters were entered:

Use time binning convolution	no
Background signal asymmetry	0.0
Remove group	no
Time range and binning size	$[0, 10, 0.001]$ μs
Start variable binning	20 μs
Power of generalized gaussian for var binning	2
Decay time of gen gaussian for var binning (us)	100
Sigma apodization time (us)	10^{14}
Sigma looseness factor	1
Test criterion (precision)	0.001
Do you want to keep the phases fixed	yes
Power for number of points	2^{15}
Min and max fields (in Telsa)	$[0, 0.005]$
Default level twiddle factor	1
Fit using sqrt(theory) as the errors?	yes

1.1.4 $\sin(\mathbf{ax})/\mathbf{x} - \sin(\mathbf{bx})/\mathbf{x} \Longrightarrow$ shifted rectangular in field

The signal parameters are as following:

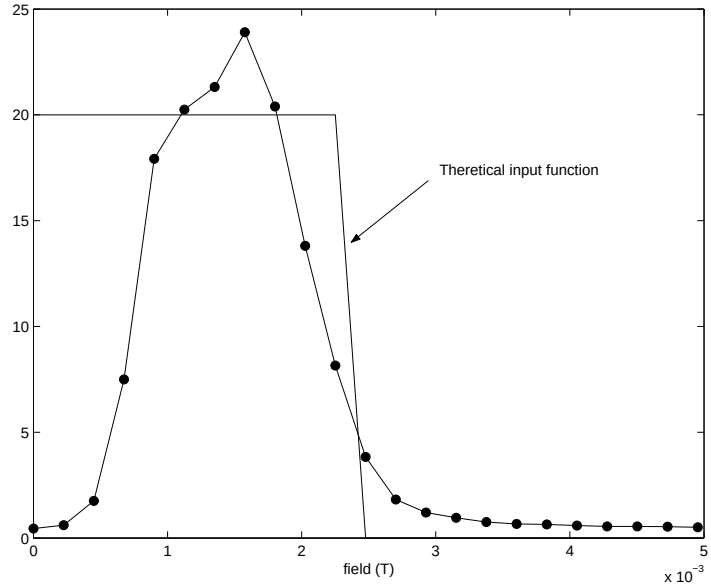

Figure 3: Result for $\sin(t)/t$ with the theoretical cut–off field of 23.457 G.

N_0	$(10^3, 0.25 \cdot 10^2)$
A_i	0.3
$f_i(t)$	$[\sin(7\omega t + \phi_i) - \sin(3\omega t + \phi_i)]/(t4\omega)$
ω	$2\text{Mc/s} \Rightarrow 23.457\text{G}$
ϕ_i	$(0, -\pi/2, \pi, \pi/2)$
B	0
binning	10^4 bins, 1 ns raster
sample with noise	Bad $\chi^2 = 1.3939$, allowed 1 ± 0.005

The following parameters were entered:

Use time binning convolution	no
Background signal asymmetry	0.0
Remove group	no
Time range and binning size	($[0, 5, 0.005]$ μs, $[0, 4, 0.005]$ μs)
Start variable binning	20 μs
Power of generalized gaussian for var binning	2
Decay time of gen gaussian for var binning (us)	100
Sigma apodization time (us)	10^{14}
Sigma looseness factor	1
Test criterion (precision)	0.001
Do you want to keep the phases fixed	yes
Power for number of points	$(2^{12}, 2^{12})$
Min and max fields (in Telsa)	$[0, 0.03]$
Default level twiddle factor	1
Fit using sqrt(theory) as the errors?	yes

1.1.5 Two pure cosine plus a rectangular in field

The signal parameters are as following:

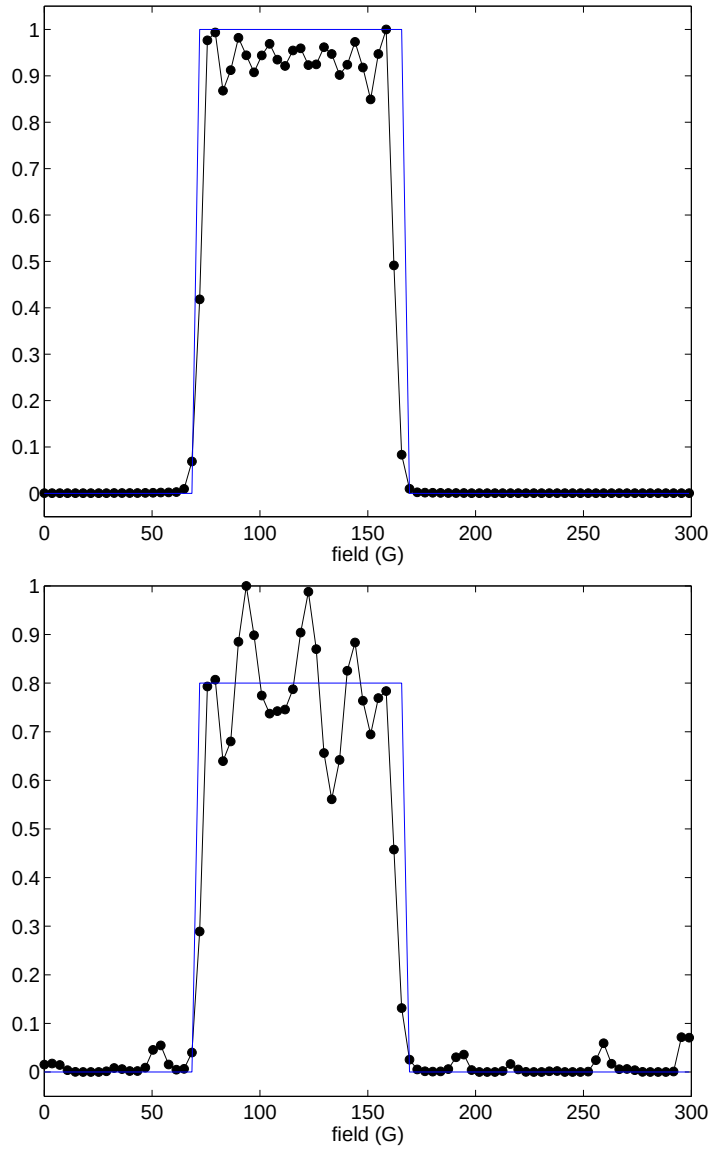

Figure 4: "Shifted $\sin(x)/x$". Top: without noise. Bottom: Noise, # of counts $\approx 2 \cdot 10^5$.

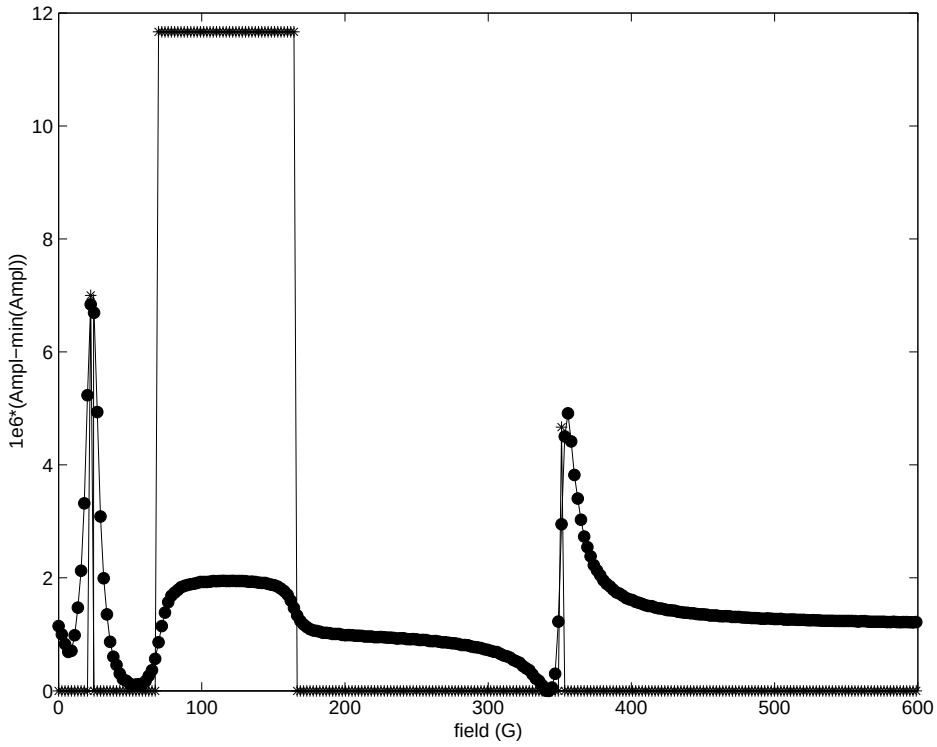

Figure 5: Two pure cosine plus "shifted $\sin(x)/x$". Amplitude strongly renormalized! Amplitudes do NOT match.

N_0	10^3
A_i	0.3
$f_i(t)$	$0.3\cos(\omega t+\phi_i)+0.2\cos(15\omega t+\phi_i+e/\sqrt{7})+0.5\left[\sin(7\omega t+\phi_i)-\sin(3\omega t+\phi_i)\right]/(t4\omega)$
ω	$2\text{Mc/s} \Rightarrow 23.457\text{G}$
ϕ_i	$(0,-\pi/2,\pi,\pi/2)$
B	0
binning	10^4 bins, 1 ns raster

The following parameters were entered:

Use time binning convolution	no
Background signal asymmetry	0.0
Remove group	no
Time range and binning size	$[0, 10, 0.001]$ μs
Start variable binning	20 μs
Power of generalized gaussian for var binning	2
Decay time of gen gaussian for var binning (us)	100
Sigma apodization time (us)	10^{14}
Sigma looseness factor	1
Test criterion (precision)	0.001
Do you want to keep the phases fixed	yes
Power for number of points	2^{15}
Min and max fields (in Telsa)	$[0, 0.06]$
Default level twiddle factor	1
Fit using sqrt(theory) as the errors?	yes

1.1.6 Lorentz and Delta

The signal parameters are as following:

N_0	10^3
A_i	0.3
$f_i(t)$	$0.9\cos(7\omega t+\phi_i)\exp(-\omega t)+0.1\cos(\alpha\omega t+\phi_i)$
ω	2Mc/s $\Rightarrow$ 23.457G
ϕ_i	$(0,-\pi/2,\pi,\pi/2)$
α	(7.123, 7.5, 8.5) three different sets of data
B	0
binning	10^4 bins, 1 ns raster

The following parameters were entered:

Use time binning convolution	no
Background signal asymmetry	0.0
Remove group	no
Time range and binning size	$[0, 10, 0.005]$ μs
Start variable binning	20 μs
Power of generalized gaussian for var binning	2
Decay time of gen gaussian for var binning (us)	100
Sigma apodization time (us)	10^{14}
Sigma looseness factor	1
Test criterion (precision)	0.001
Do you want to keep the phases fixed	yes
Power for number of points	2^{13}
Min and max fields (in Telsa)	$[0, 0.03]$
Default level twiddle factor	1
Fit using sqrt(theory) as the errors?	yes

1.1.7 Lorentz

The signal parameters are as following:

N_0	10^3
A_i	0.3
$f_i(t)$	$\cos(7\omega t+\phi_i)\exp(-\omega t)$
ω	2Mc/s $\Rightarrow$ 23.457G
ϕ_i	$(0,-\pi/2,\pi,\pi/2)$
B	0
binning	10^4 bins, 1 ns raster

The Fourier–transform of $f_i(t)$

$$\cos(\omega_1 t)e^{-at} \Longrightarrow N\frac{a}{a^2+(\omega-\omega_1)^2}+\frac{a}{a^2+(\omega+\omega_1)^2}$$

and N is a constant which depends on the definition of the Fourier–transform.
The following parameters were entered:

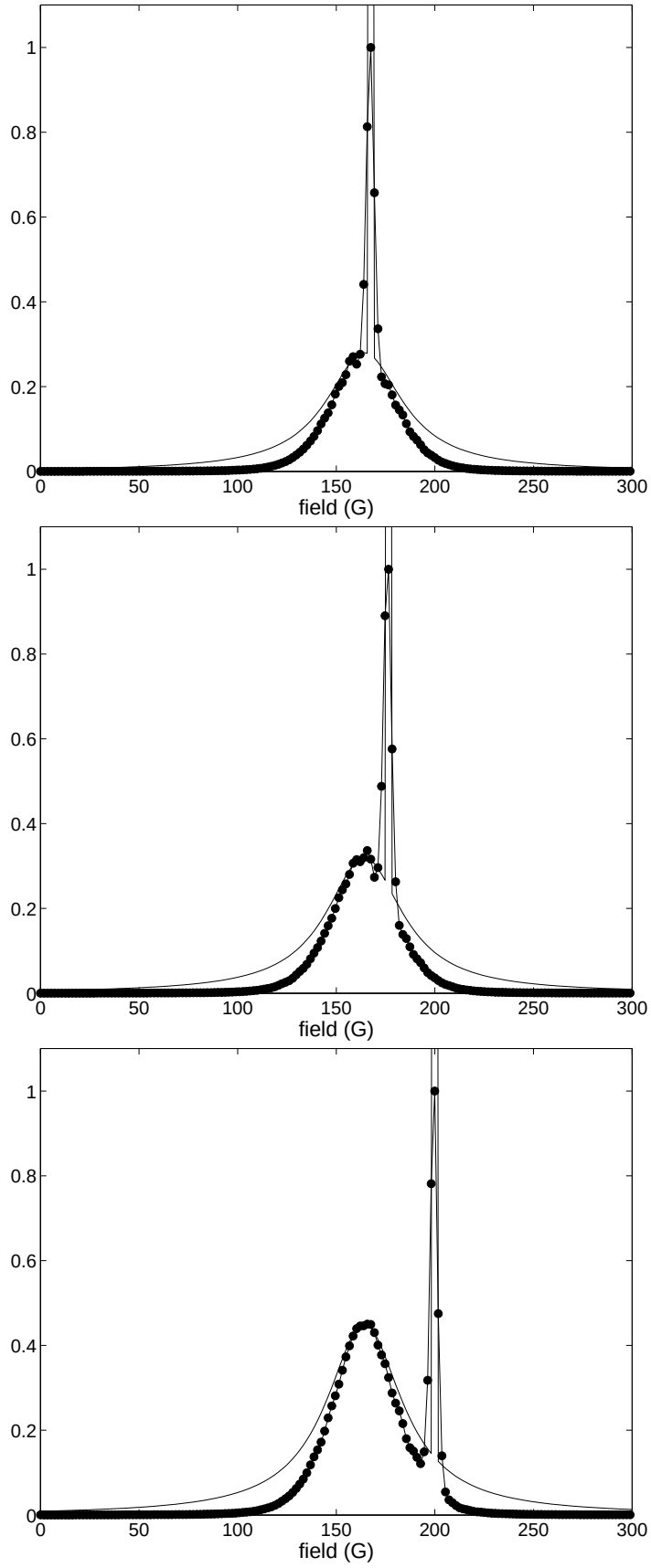

Figure 6: Lorentz plus Delta.

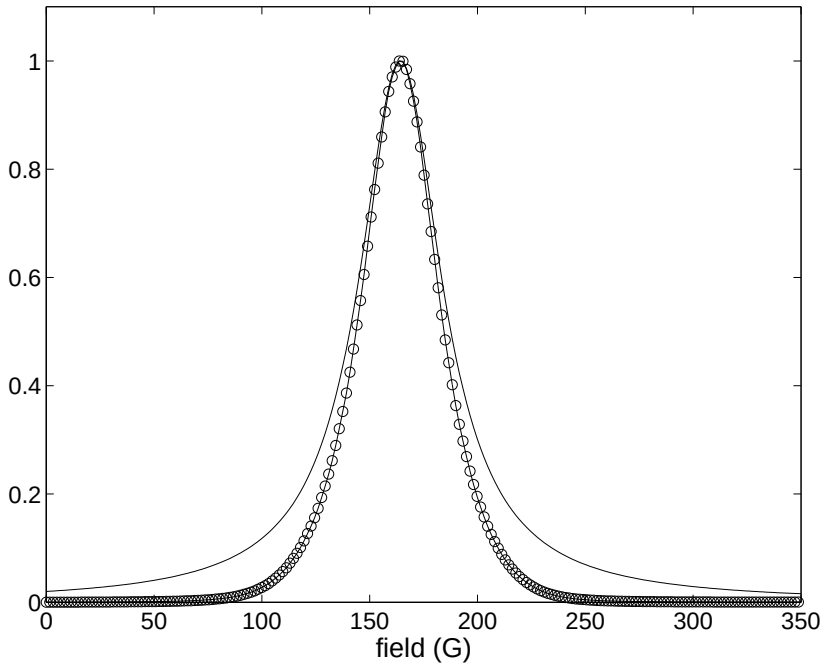

Figure 7: Lorentz?

Use time binning convolution	no
Background signal asymmetry	0.0
Remove group	no
Time range and binning size	$[0, 10, 0.005]$ μs
Start variable binning	20 μs
Power of generalized gaussian for var binning	2
Decay time of gen gaussian for var binning (us)	100
Sigma apodization time (us)	10^{14}
Sigma looseness factor	1
Test criterion (precision)	0.001
Do you want to keep the phases fixed	yes
Power for number of points	2^{13}
Min and max fields (in Telsa)	$[0, 0.035]$
Default level twiddle factor	1
Fit using sqrt(theory) as the errors?	yes

1.1.8 Gauss

The signal parameters are as following:

N_0	10^3
A_i	0.3
$f_i(t)$	$\cos(9\omega t + \phi_i)\exp(-\omega^2 t^2)$
ω	2Mc/s $\Rightarrow$ 23.457G
ϕ_i	$(0, -\pi/2, \pi, \pi/2)$
B	0
binning	10^4 bins, 1 ns raster

The following parameters were entered:

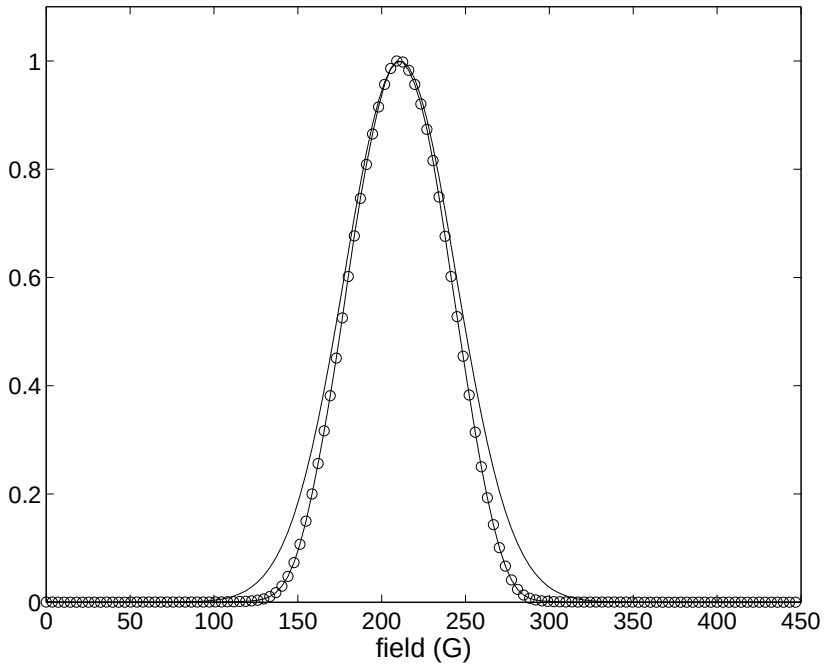

Figure 8: Gauss

Use time binning convolution	no
Background signal asymmetry	0.0
Remove group	no
Time range and binning size	$[0, 3, 0.005]$ μs
Start variable binning	20 μs
Power of generalized gaussian for var binning	2
Decay time of gen gaussian for var binning (us)	100
Sigma apodization time (us)	10^{14}
Sigma looseness factor	1
Test criterion (precision)	0.001
Do you want to keep the phases fixed	yes
Power for number of points	2^{12}
Min and max fields (in Telsa)	$[0, 0.05]$
Default level twiddle factor	1
Fit using sqrt(theory) as the errors?	yes

1.1.9 Two Gauss

The signal parameters are as following:

N_0	10^3
A_i	0.3
$f_i(t)$	$0.3\cos(9\omega t + \phi_i)\exp(-\omega^2 t^2) + 0.7\cos(11\omega t + \phi_i)\exp(-0.1\omega^2 t^2)$
ω	2Mc/s $\Rightarrow$ 23.457G
ϕ_i	$(0, -\pi/2, \pi, \pi/2)$
B	0
binning	10^4 bins, 1 ns raster

The following parameters were entered:

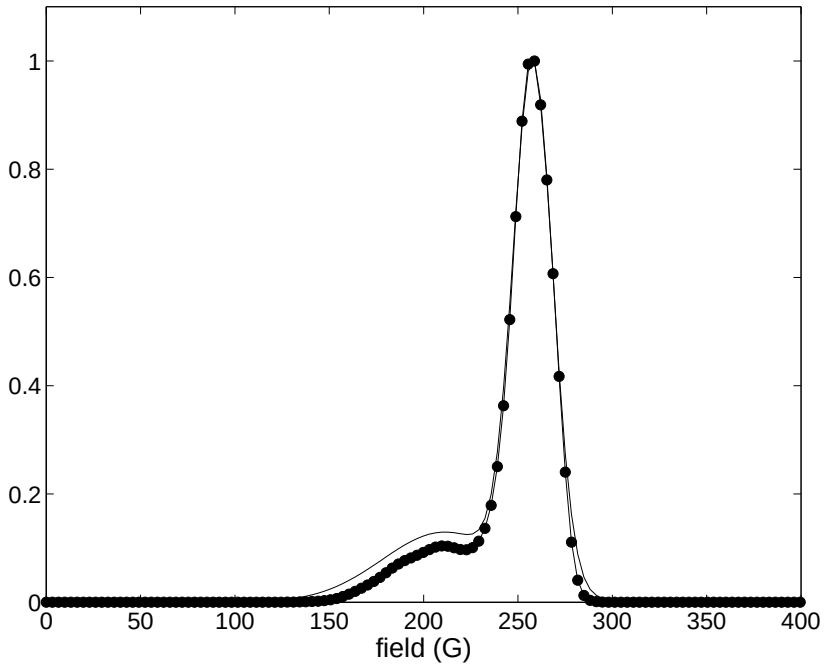

Figure 9: Two Gauss

Use time binning convolution	no
Background signal asymmetry	0.0
Remove group	no
Time range and binning size	$[0, 3, 0.01]$ μs
Start variable binning	20 μs
Power of generalized gaussian for var binning	2
Decay time of gen gaussian for var binning (us)	100
Sigma apodization time (us)	10^{14}
Sigma looseness factor	1
Test criterion (precision)	0.001
Do you want to keep the phases fixed	yes
Power for number of points	2^{11}
Min and max fields (in Telsa)	$[0, 0.04]$
Default level twiddle factor	1
Fit using sqrt(theory) as the errors?	yes

1.1.10 Two Gauss

The signal parameters are as following:

N_0	10^3
A_i	0.3
$f_i(t)$	$0.3\cos(9\omega t + \phi_i)\exp(-\omega^2 t^2) + 0.7\cos(11\omega t + \phi_i)\exp(-0.1\omega^2 t^2)$
ω	2Mc/s $\Rightarrow$ 23.457G
ϕ_i	$(0, -\pi/2, \pi, \pi/2)$
B	0
binning	10^4 bins, 1 ns raster
(1) # of counts in detector (1–4)	2179052, 2161835, 2177693, 2188862
(2) # of counts in detector (1–4)	217810, 215534, 217572, 219396
(3) # of counts in detector (1–4)	53948, 53519, 54156, 54730

The following parameters were entered:

Use time binning convolution	no
Background signal asymmetry	0.0
Remove group	no
Time range and binning size	(1) $[0, 4, 0.01]$ μs, (2) $[0, 3.5, 0.005]$ μs (3) $[0, 3, 0.001]$ μs
Start variable binning	20 μs
Power of generalized gaussian for var binning	2
Decay time of gen gaussian for var binning (us)	100
Sigma apodization time (us)	10^{11}
Sigma looseness factor	1
Test criterion (precision)	0.001
Do you want to keep the phases fixed	yes
Power for number of points	(1) 2^{11}, (2) 2^{12}, (3) 2^{13}
Min and max fields (in Telsa)	$[0, 0.035]$
Default level twiddle factor	1
Fit using sqrt(theory) as the errors?	yes

1.1.11 Lorentz plus Delta with bad statistics

The signal parameters are as following:

N_0	10^3
A_i	0.3
$f_i(t)$	$0.9\cos(7\omega t + \phi_i)\exp(-\omega t) + 0.1\cos(7.5\omega t + \phi_i)$
ω	2Mc/s $\Rightarrow$ 23.457G
ϕ_i	$(0, -\pi/2, \pi, \pi/2)$
B	0
binning	10^4 bins, 1 ns raster

The following parameters were entered:

Use time binning convolution	no
Background signal asymmetry	0.0
Remove group	no
Time range and binning size	$[0, 9, 0.001]$ μs
Start variable binning	20 μs
Power of generalized gaussian for var binning	2
Decay time of gen gaussian for var binning (us)	100
Sigma apodization time (us)	10^{16}
Sigma looseness factor	1
Test criterion (precision)	0.001
Do you want to keep the phases fixed	yes
Power for number of points	2^{16}
Min and max fields (in Telsa)	$[0, 0.03]$
Default level twiddle factor	1
Fit using sqrt(theory) as the errors?	yes
Bad $\chi^2 = 1.0658$	allowed would be 1 ± 0.00527

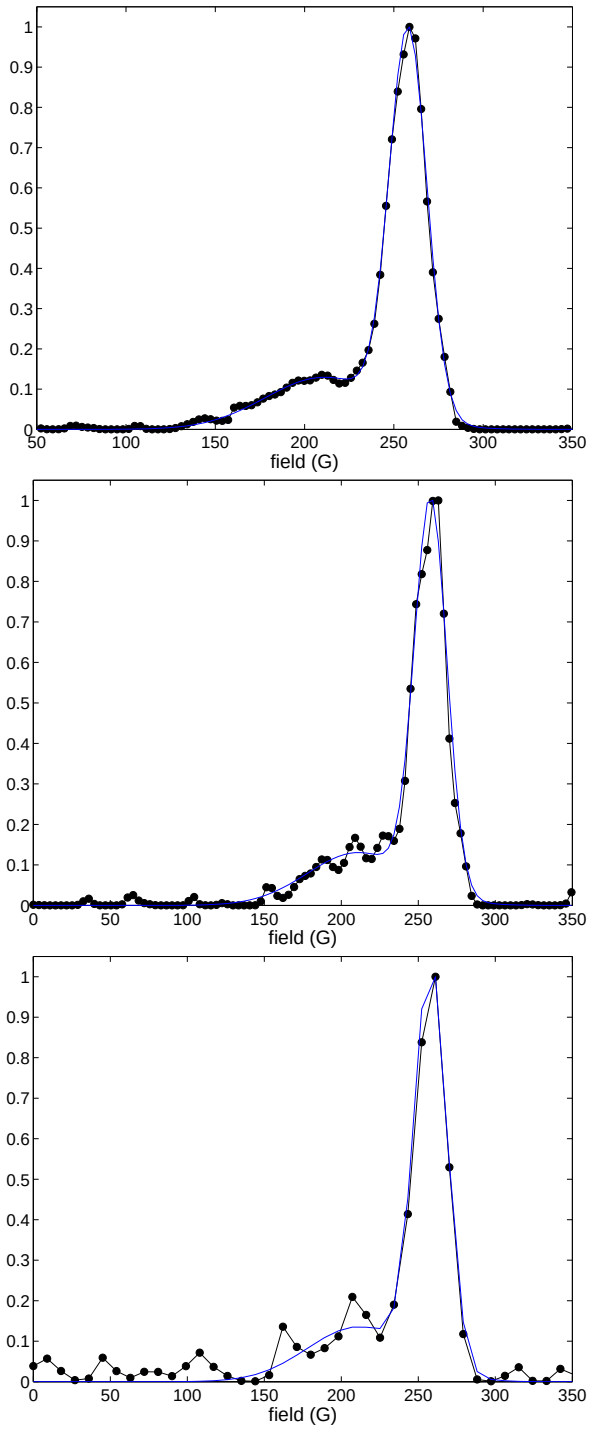

Figure 10: Two Gauss — Top: $\approx 8.7 \cdot 10^6$ total counts, Middle: $\approx 8.7 \cdot 10^5$ total counts, Bottom: $\approx 2.1 \cdot 10^5$ total counts

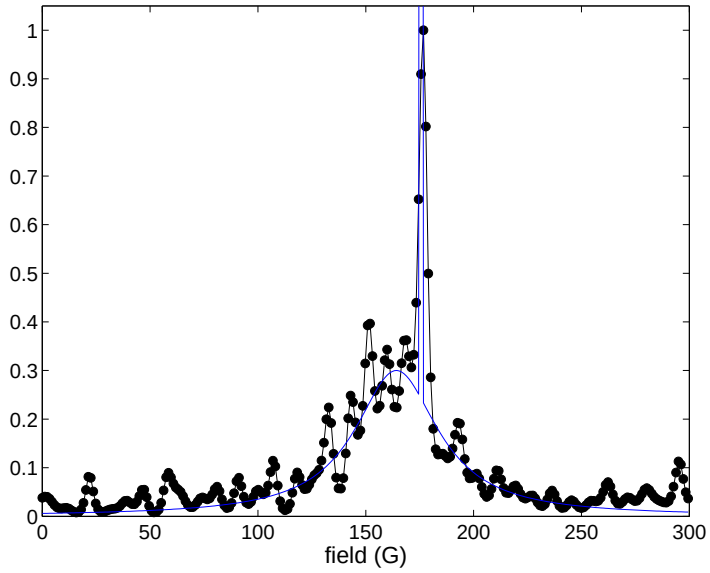

Figure 11: Lorentz plus Delta. Total # of counts $\approx 2.2 \cdot 10^4$

1.1.12 Saw Tooth

A saw tooth signal, given as

$$F(\omega) = \begin{cases} a\omega + b, & \omega \in [-b/a, c] \\ 0, & \text{else} \end{cases}$$

There are three signals calculated with different noise levels. The first without any noise. The other two with their corresponding Poisson noise. The signal parameters are as following:

N_0	$(10^3, 10^3, 0.25 \cdot 10^2)$
A_i	0.3
$f_i(t)$	$\frac{a[\cos(ct+\phi_i) - \cos(bt/a+\phi_i)] + (b+ac)t\sin(ct+\phi_i)}{t^2}$
(a, b, c)	$(0.1, -5a\omega, 9\omega)$
ω	$2\text{Mc/s} \Rightarrow 23.457\text{G}$
ϕ_i	$(0, -\pi/2, \pi, \pi/2)$
B	0
binning	10^4 bins, 1 ns raster

The following parameters were entered:

Use time binning convolution	no
Background signal asymmetry	0.0
Remove group	no
Time range and binning size	($[0, 5, 0.005]$ μs, $[0, 5, 0.005]$ μs, $[0, 5, 0.01]$ μs)
Start variable binning	20 μs
Power of generalized gaussian for var binning	2
Decay time of gen gaussian for var binning (us)	100
Sigma apodization time (us)	10^{15}
Sigma looseness factor	1
Test criterion (precision)	0.001
Do you want to keep the phases fixed	yes
Power for number of points	$(10^{12}, 10^{12}, 10^{11})$
Min and max fields (in Telsa)	$[0, 0.03]$
Default level twiddle factor	1
Fit using sqrt(theory) as the errors?	yes

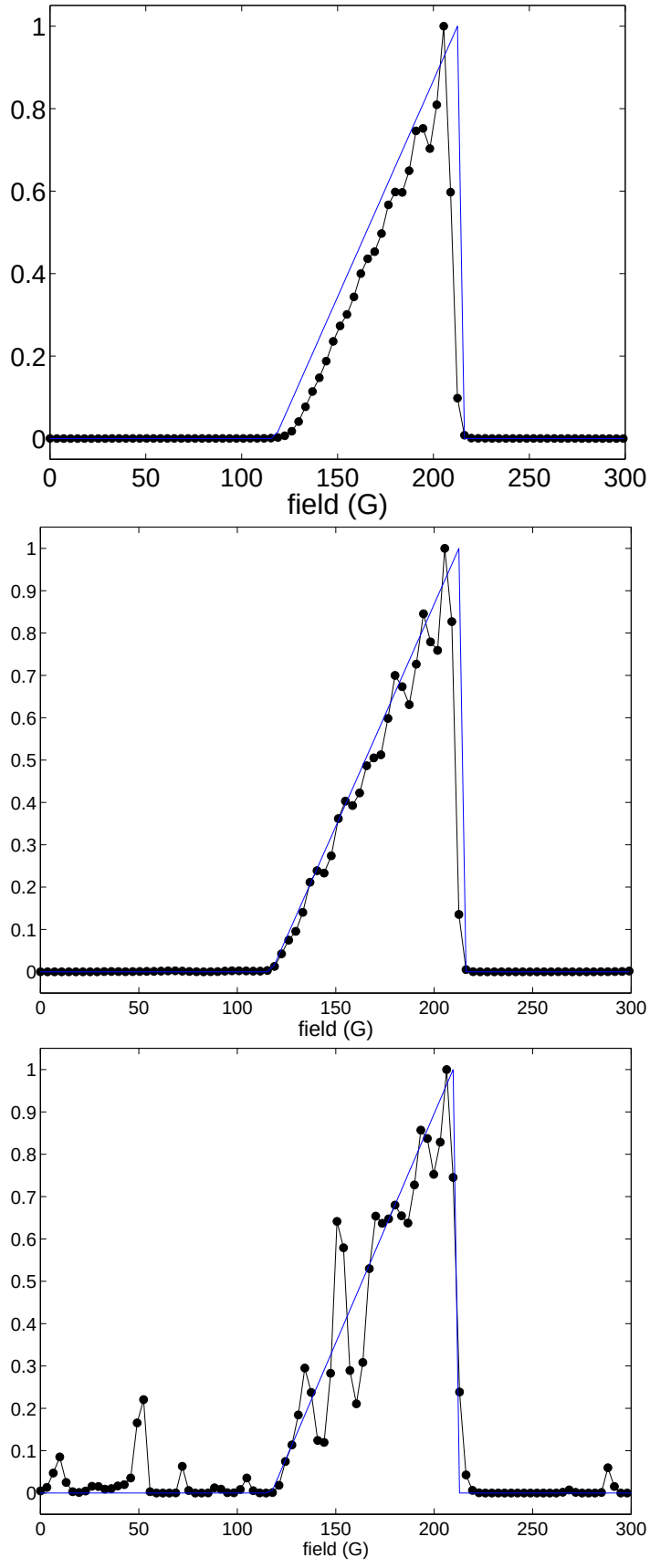

Figure 12: Saw tooth. Top: No noise. Middle: Total # of counts $\approx 8 \cdot 10^6$. Bottom: Total # of counts $\approx 2 \cdot 10^5$.