True coincidences and a Decent Currie

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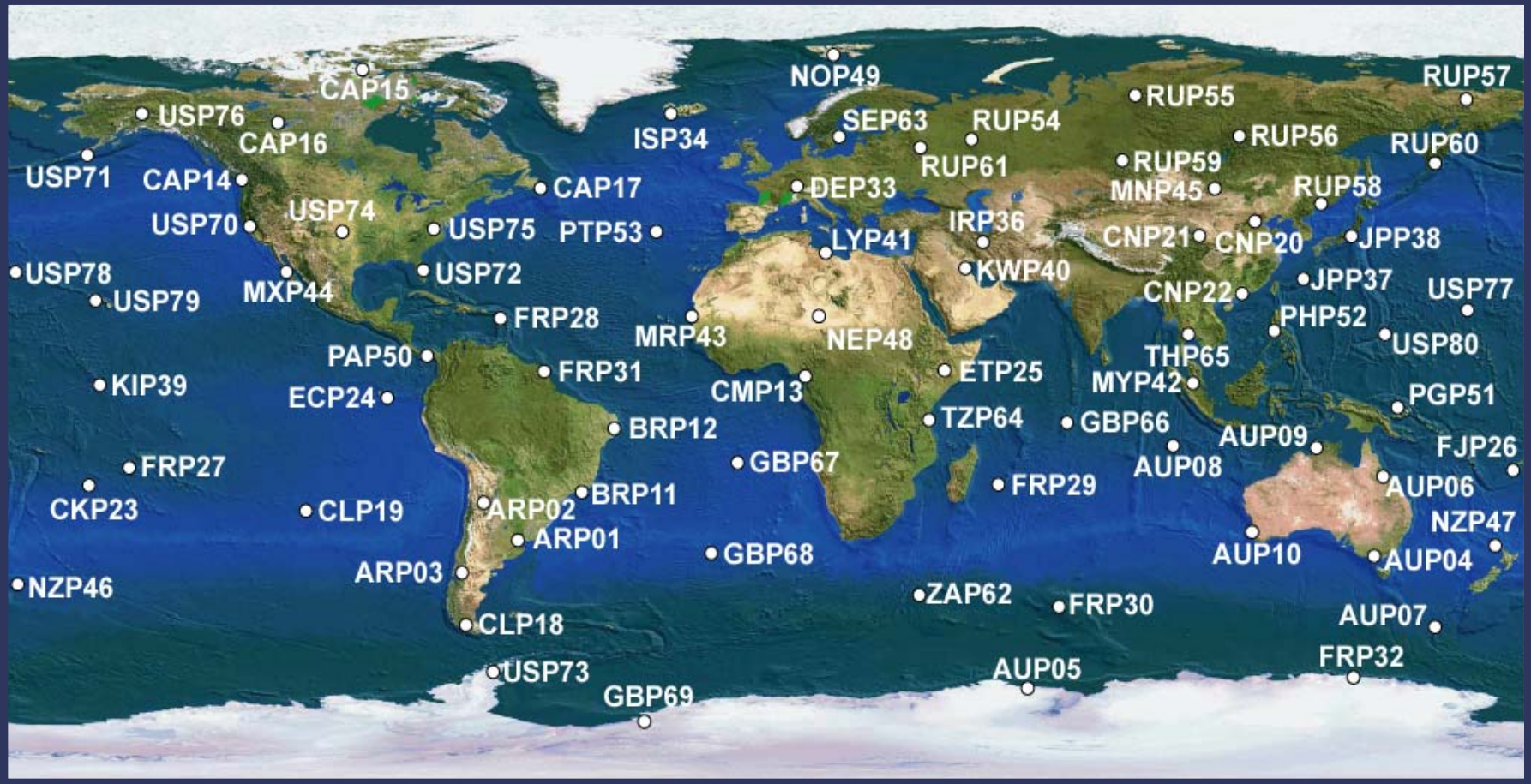
Radionuclide Particulate Station Network 79 + 1 TBD



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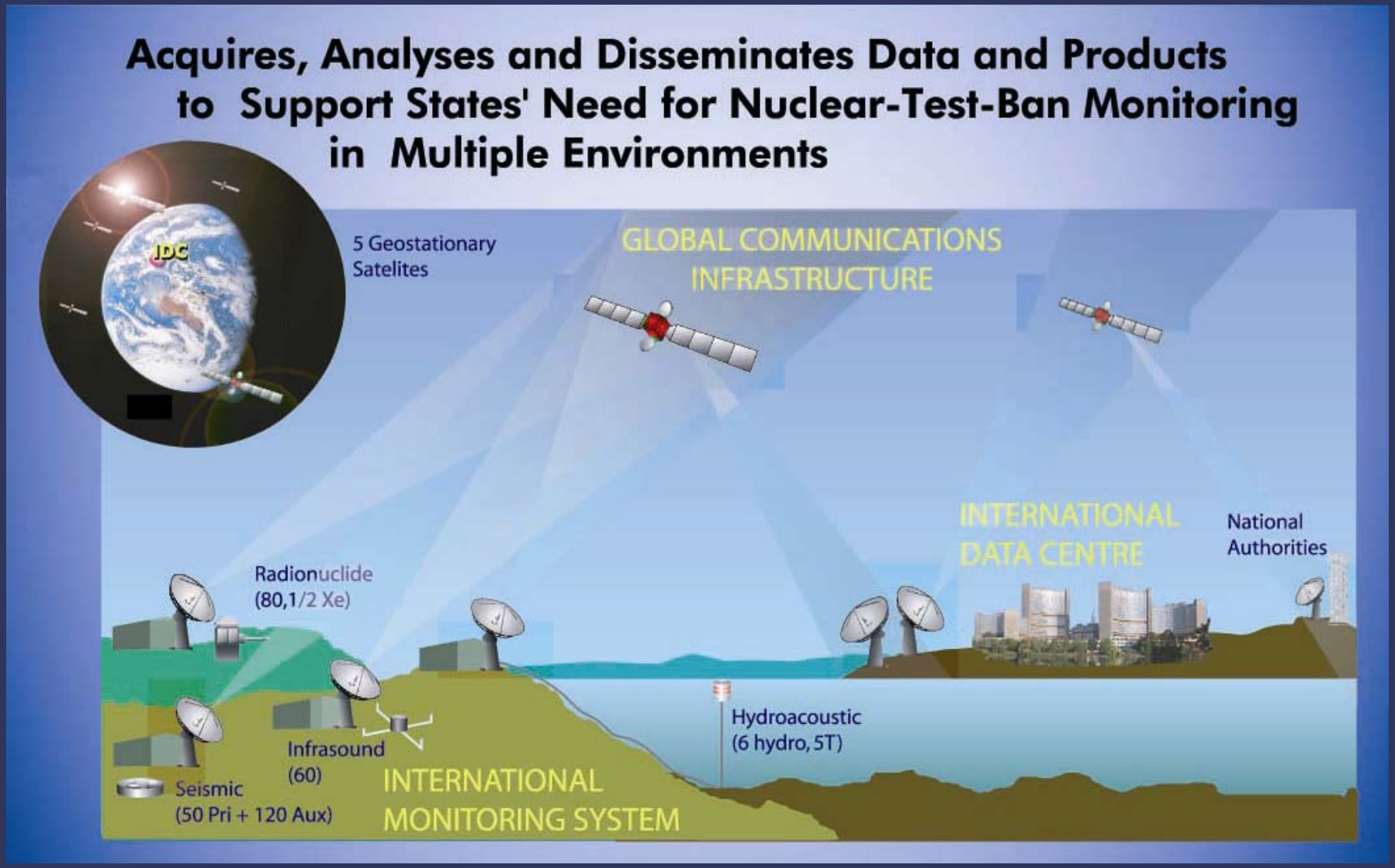
SAUNA – Swedish Automatic Unit for Noble gas Acquisition

FOI

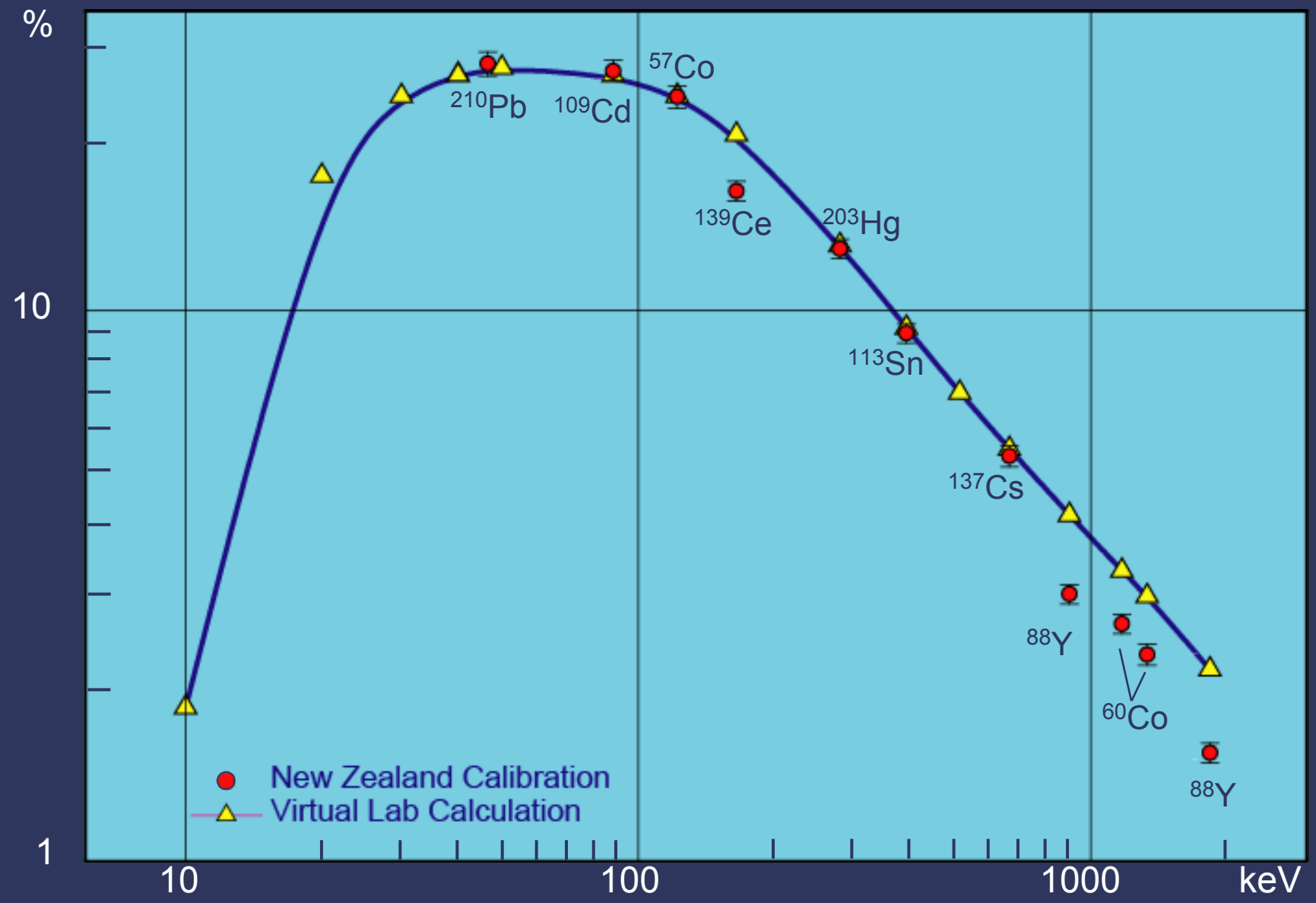


The CTBT Verification Regime

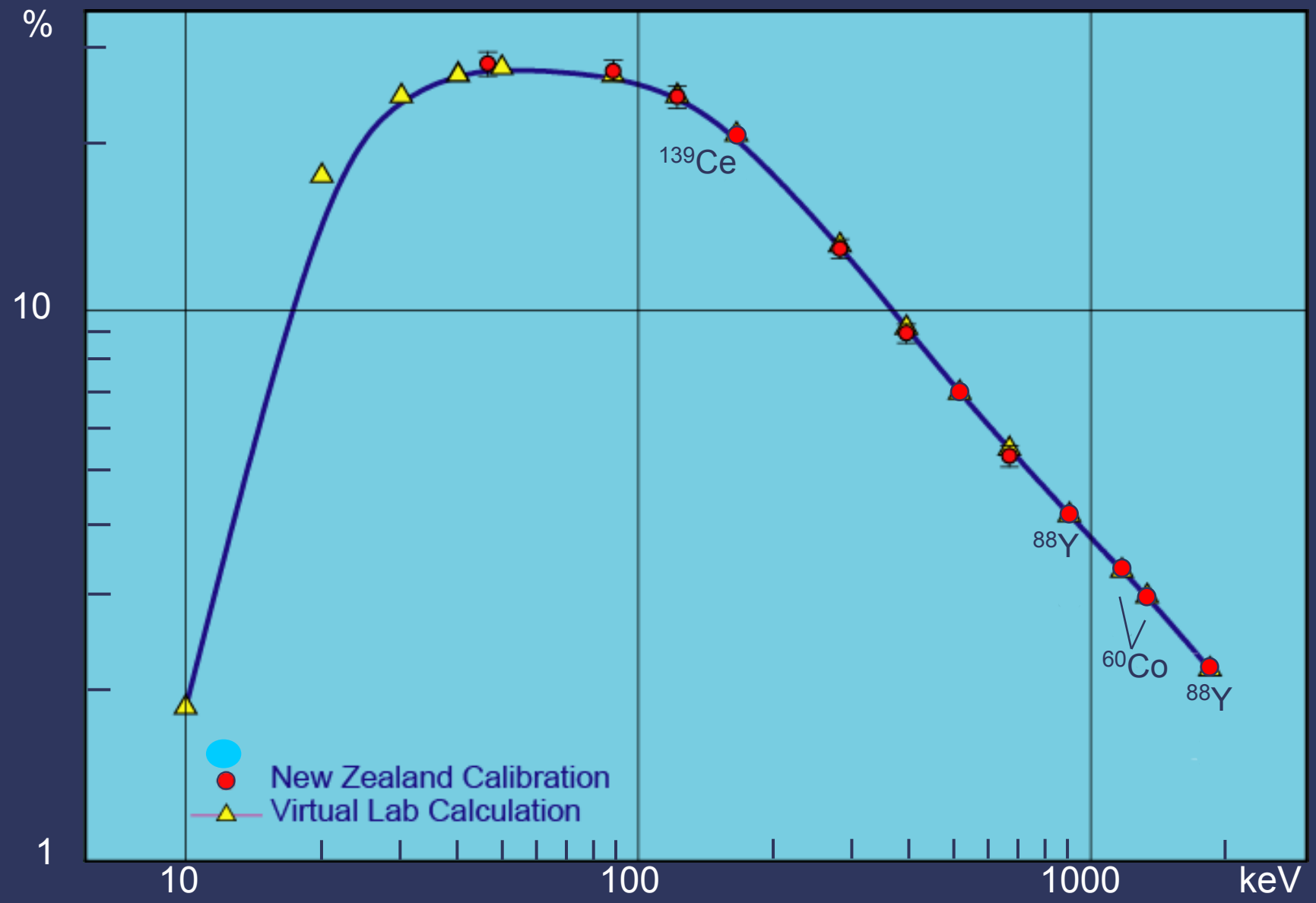
TCS

True Coincidence Summation

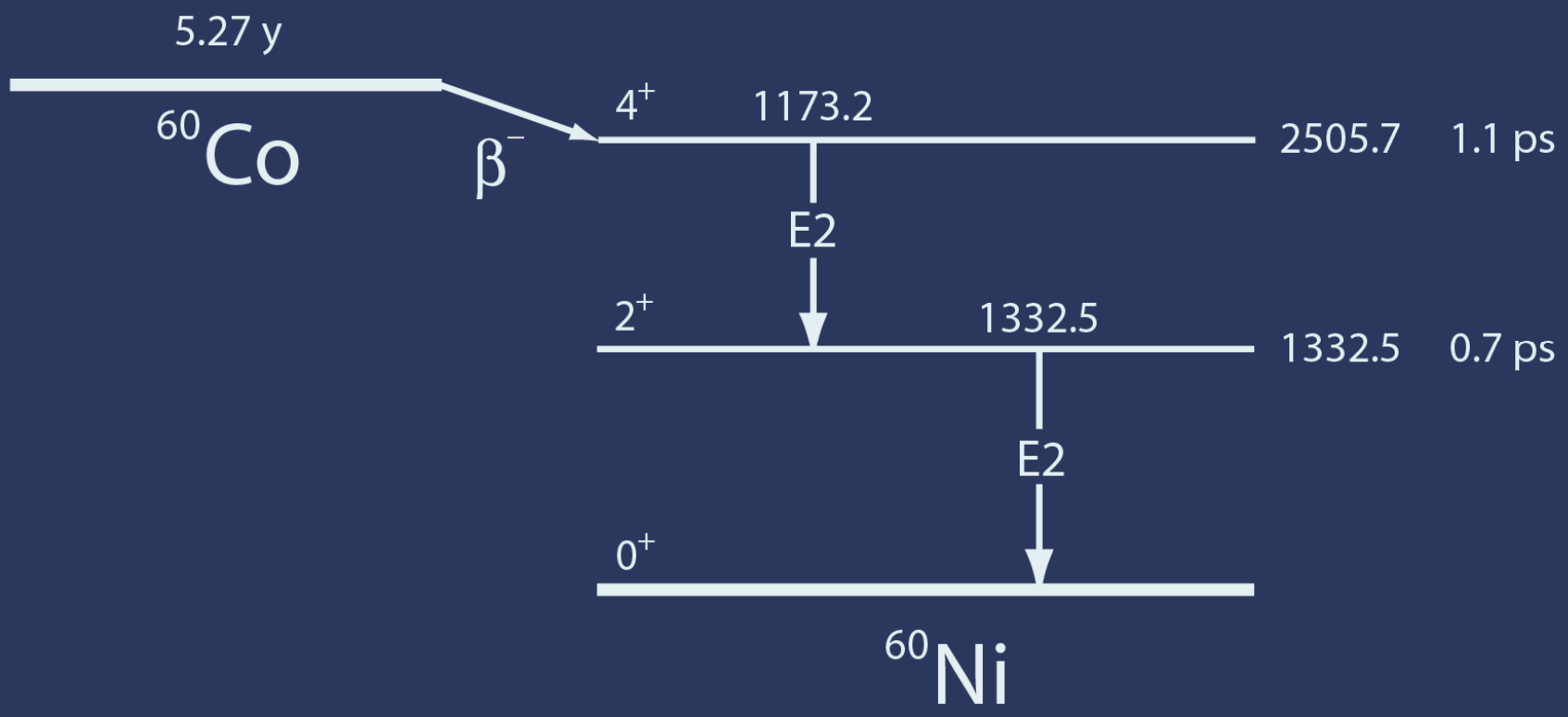
FOI


%
10
1
10
100
1000
keV
210Pb
109Cd
57Co
139Ce
203Hg
113Sn
137Cs
88Y
60Co
88Y
New Zealand Calibration
Virtual Lab Calculation

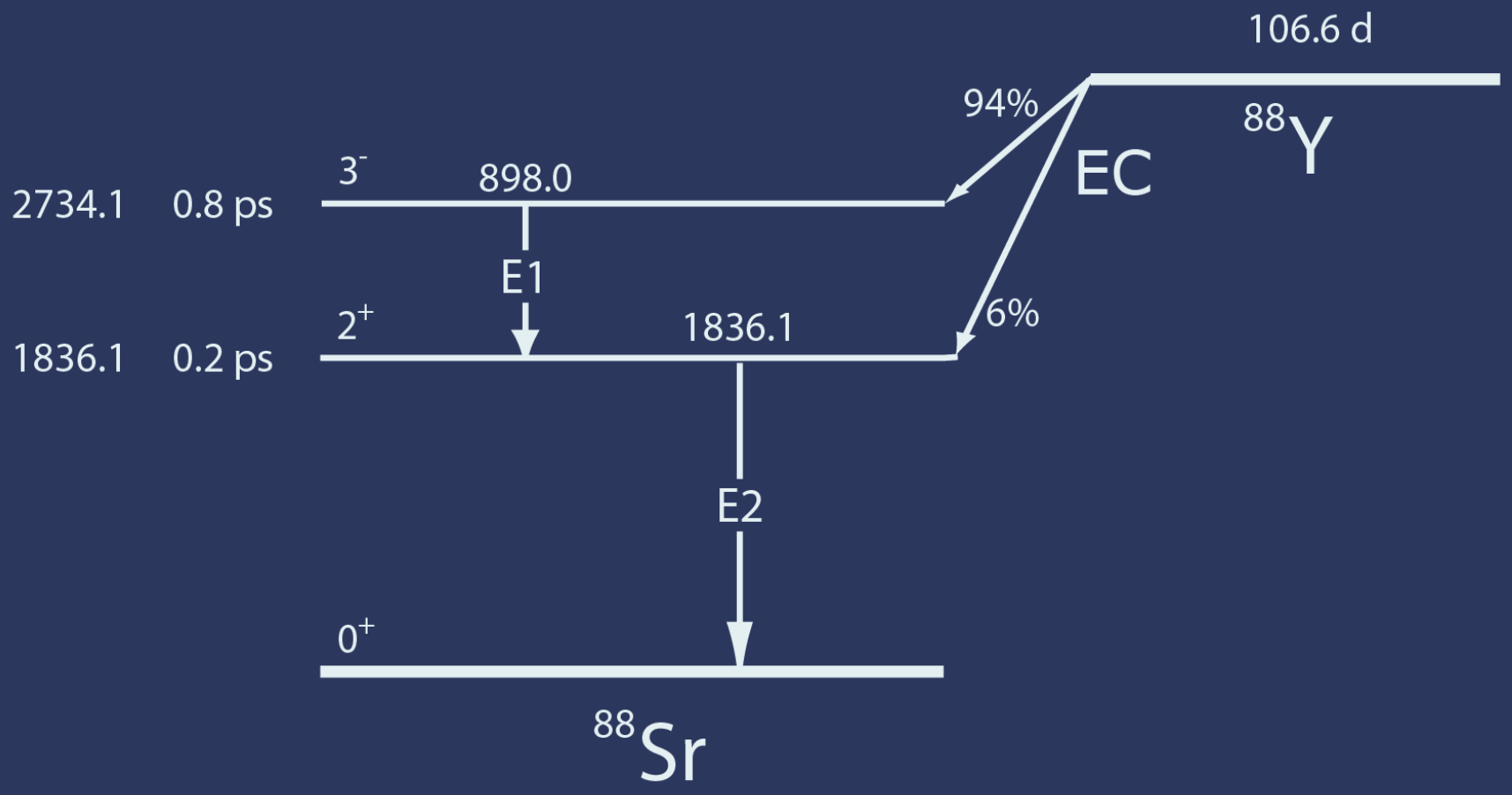
FOI


%
10
1
10
100
1000
keV
139Ce
88Y
60Co
88Y
New Zealand Calibration
Virtual Lab Calculation

FOI



FOI


106.6 d
94%
88Y
EC
3-
898.0
2734.1
0.8 ps
E1
2+
1836.1
6%
1836.1
0.2 ps
E2
0+
88Sr

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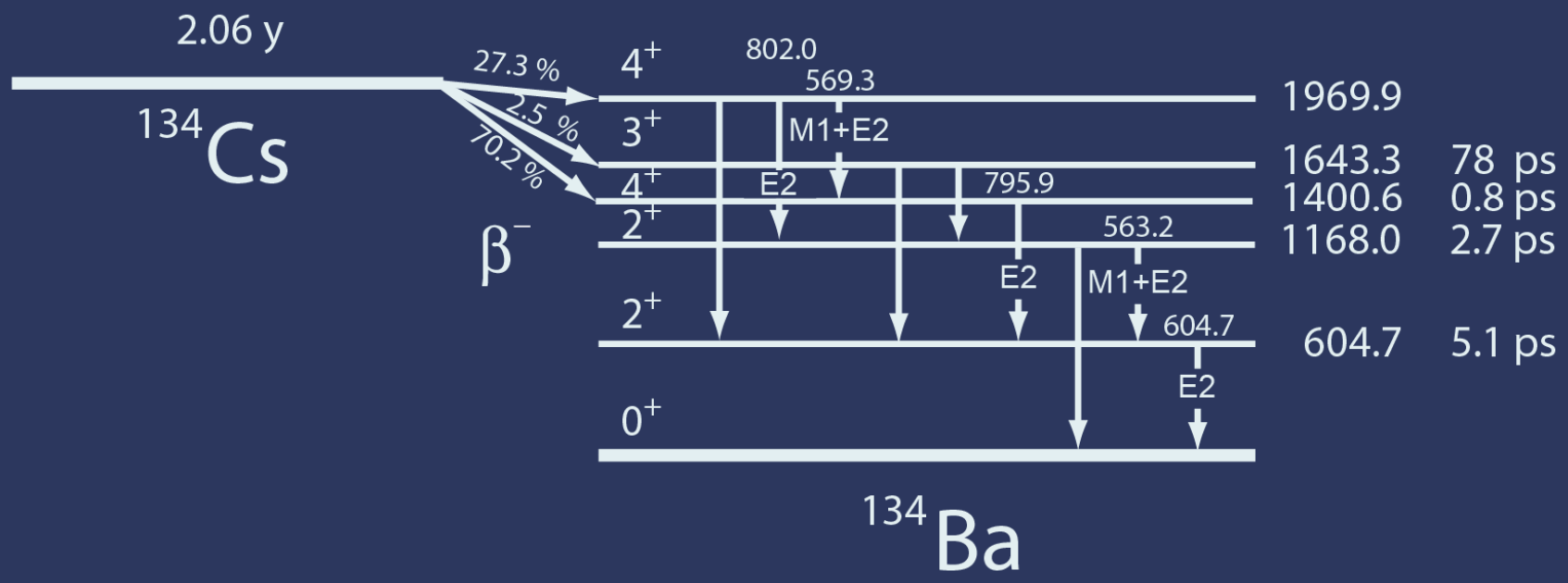
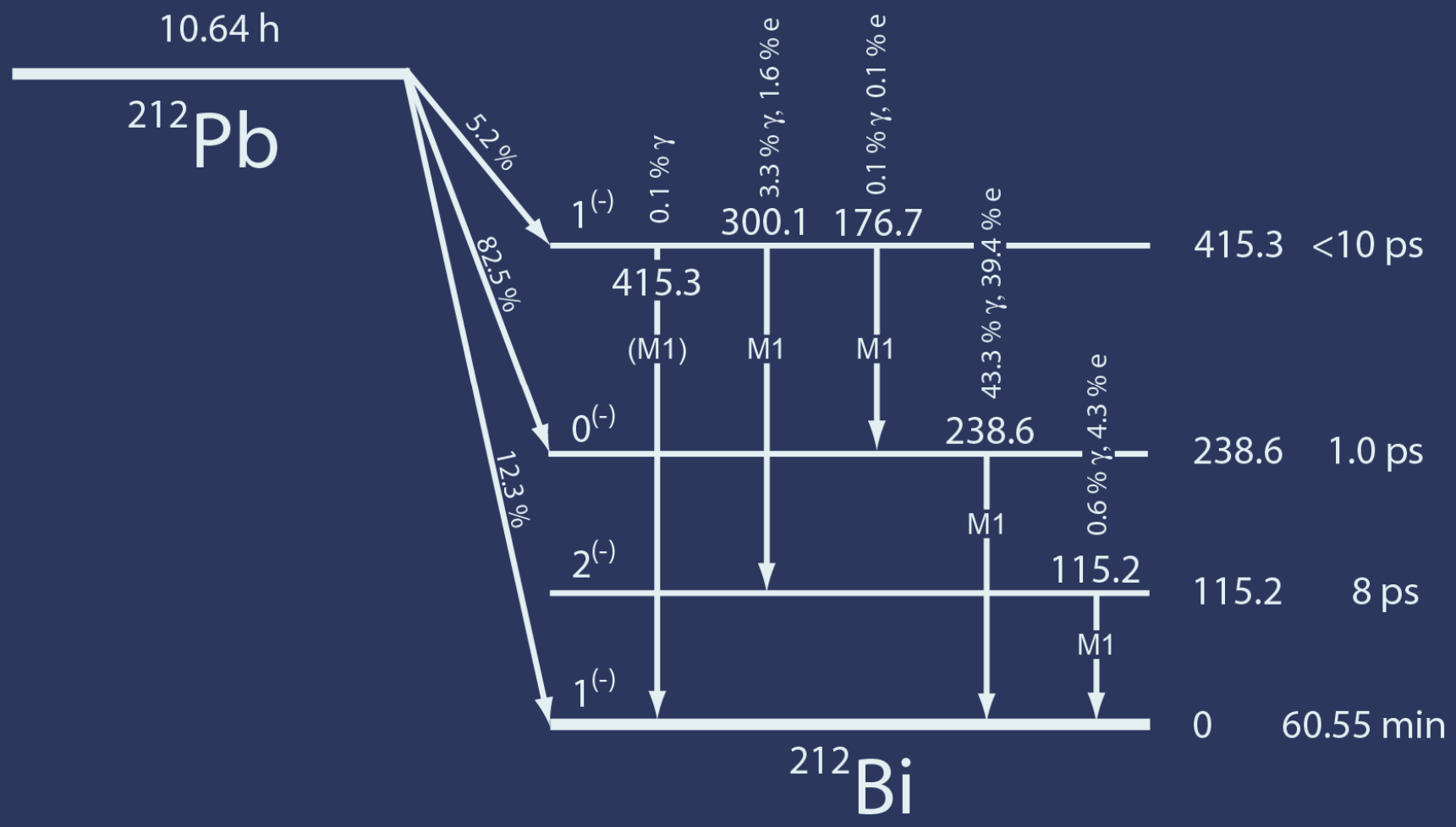
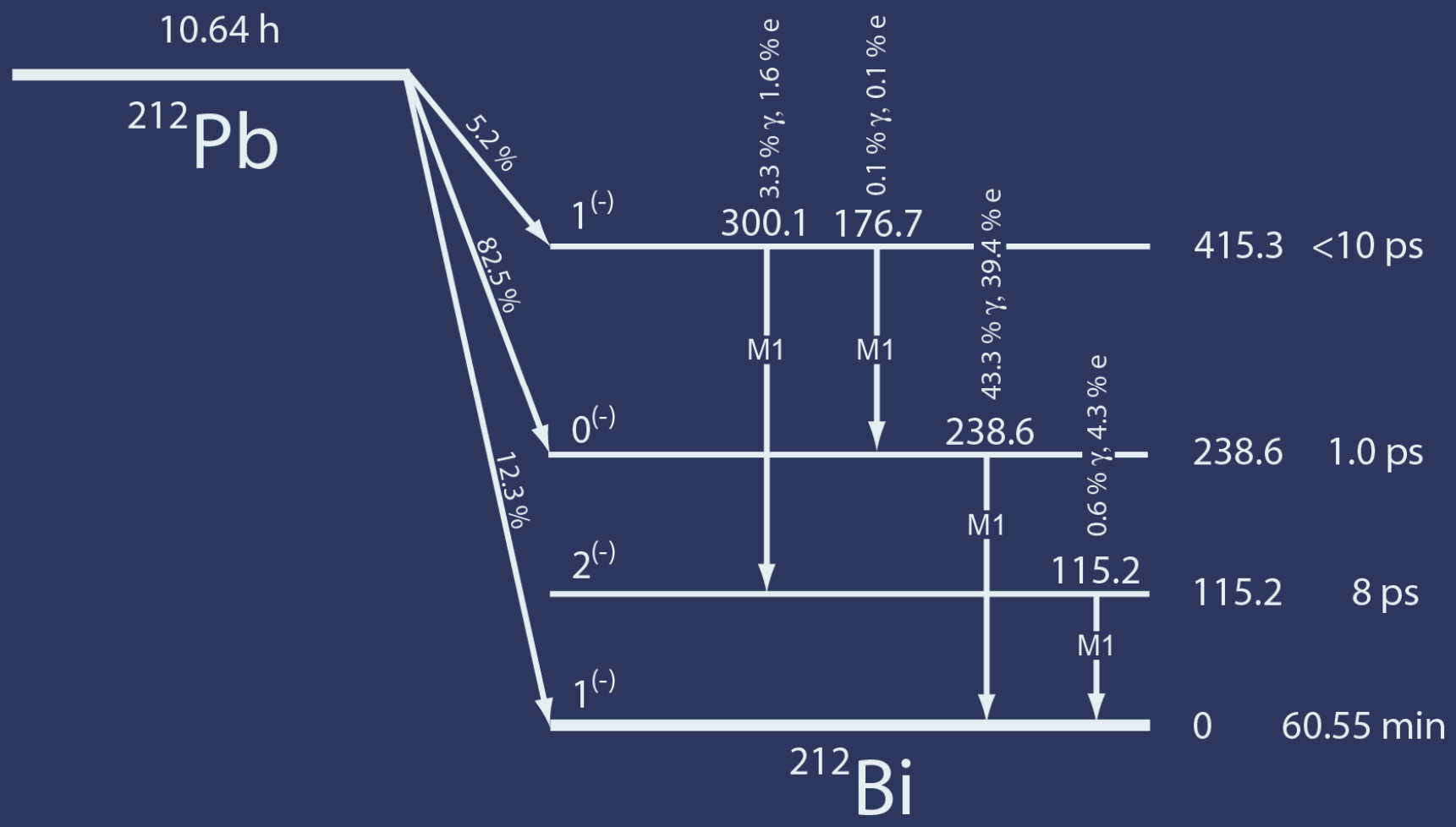
137.6 d
E1
165.9
5/2+
165.9
1.5 ns
EC
139Ce
7/2+
139La


2.06 y
134Cs
27.3 %
2.5 %
70.2 %
β−
4+
3+
4+
2+
2+
0+
802.0
569.3
M1+E2
E2
795.9
563.2
E2
M1+E2
604.7
E2
1969.9
1643.3 78 ps
1400.6 0.8 ps
1168.0 2.7 ps
604.7 5.1 ps
134Ba

FOI

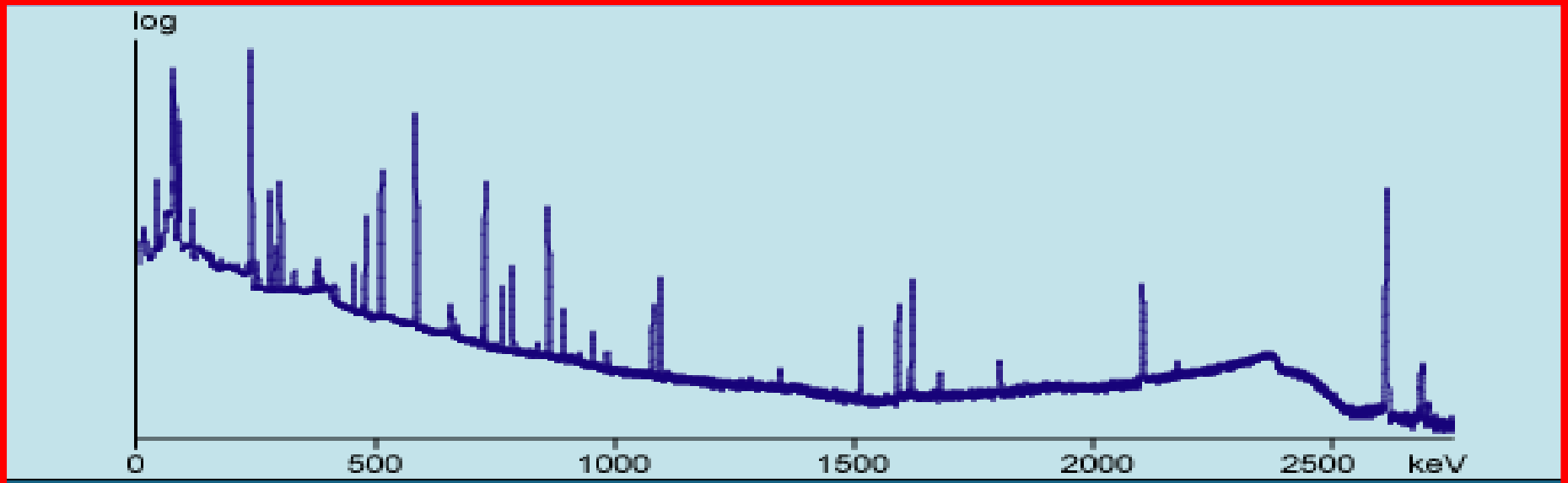

10.64 h
212Pb
5.2 %
82.5 %
12.3 %
1(-)
0(-)
2(-)
1(-)
0.1 % γ
3.3 % γ, 1.6 % e
0.1 % γ, 0.1 % e
43.3 % γ, 39.4 % e
0.6 % γ, 4.3 % e
300.1
176.7
415.3
238.6
115.2
(M1)
M1
M1
M1
M1
415.3 <10 ps
238.6 1.0 ps
115.2 8 ps
0 60.55 min
212Bi

FOI


10.64 h
212Pb
5.2 %
82.5 %
12.3 %
1(-)
0(-)
2(-)
1(-)
3.3 % γ, 1.6 % e
0.1 % γ, 0.1 % e
300.1
176.7
43.3 % γ, 39.4 % e
238.6
0.6 % γ, 4.3 % e
115.2
M1
M1
M1
M1
415.3 <10 ps
238.6 1.0 ps
115.2 8 ps
0 60.55 min
212Bi

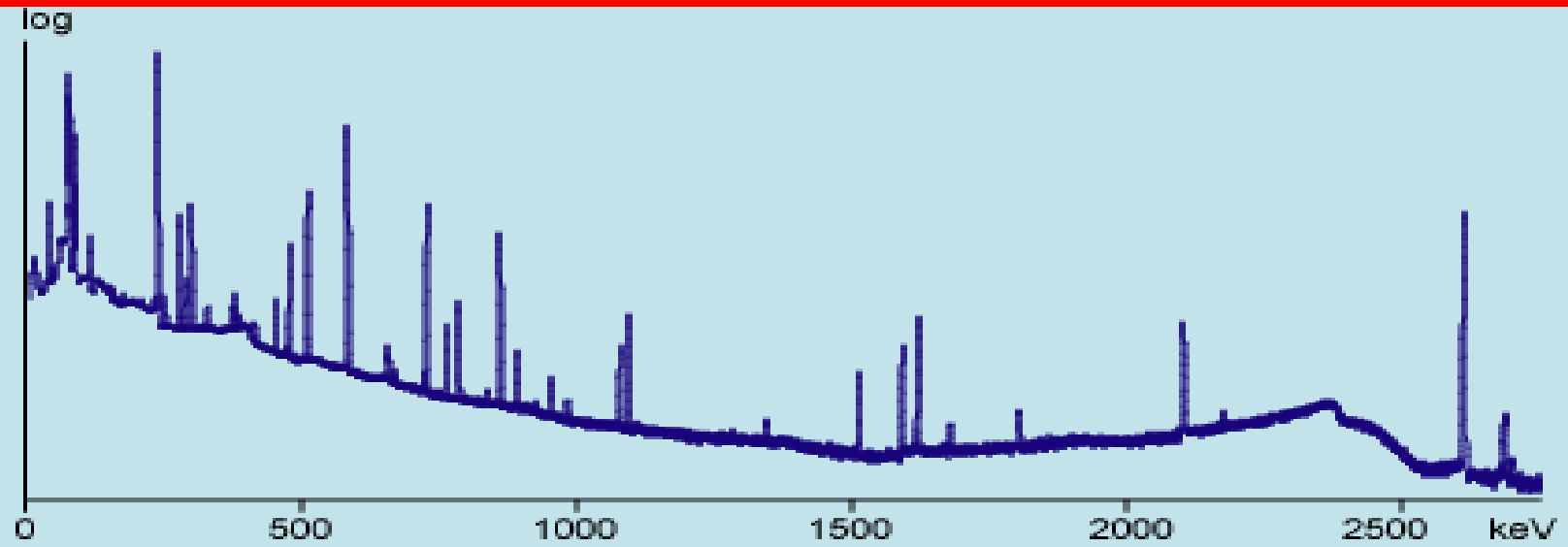
FOI

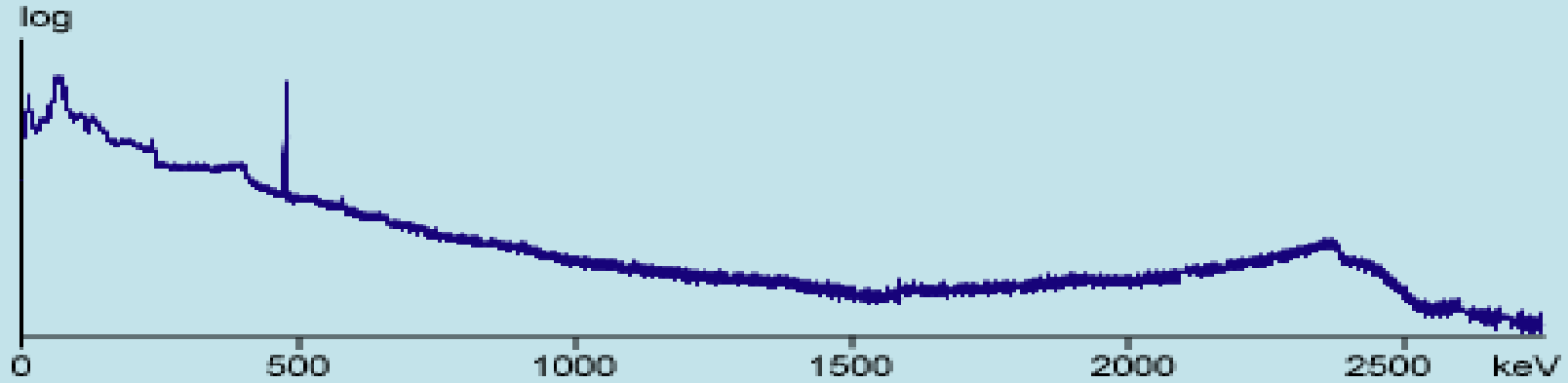
The Lead Picker



FOI

The Lead Picker





FOI

Sinnko

Debertin

Aaltonen, Ugletveit

Korsum

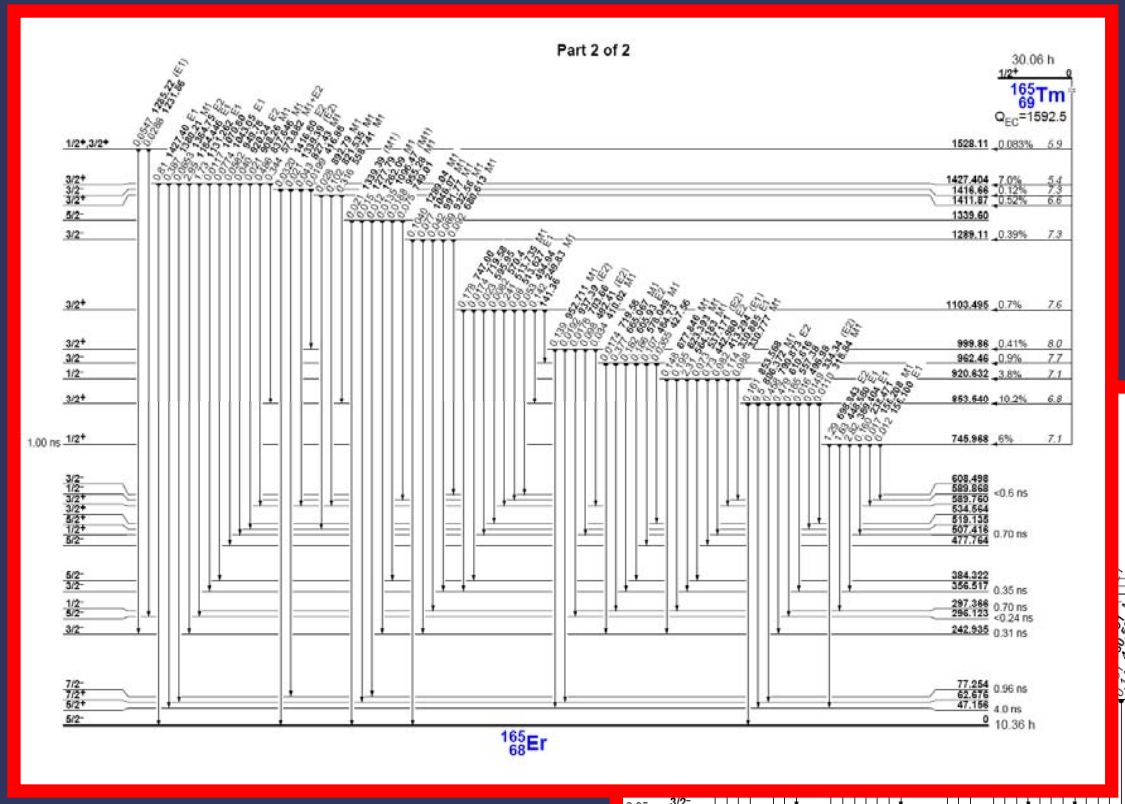
Shaman

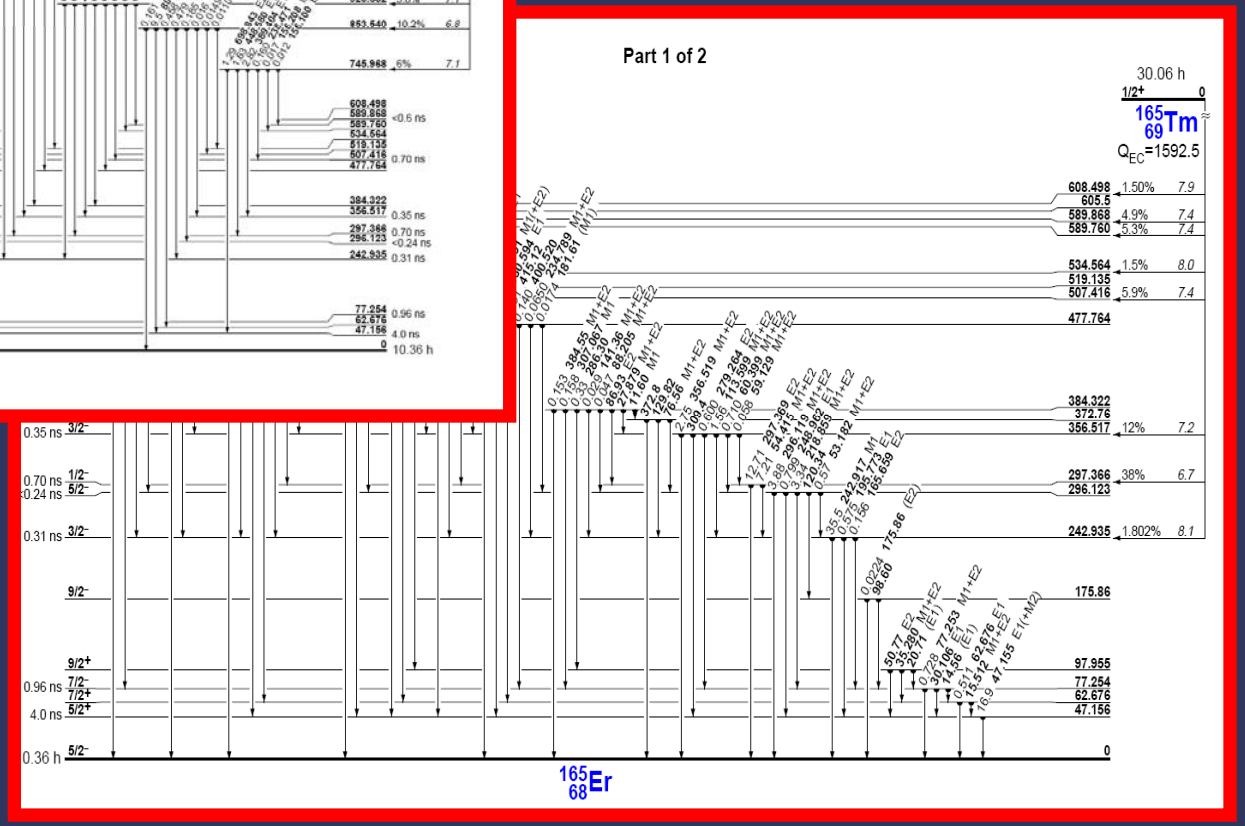
GESPECOR

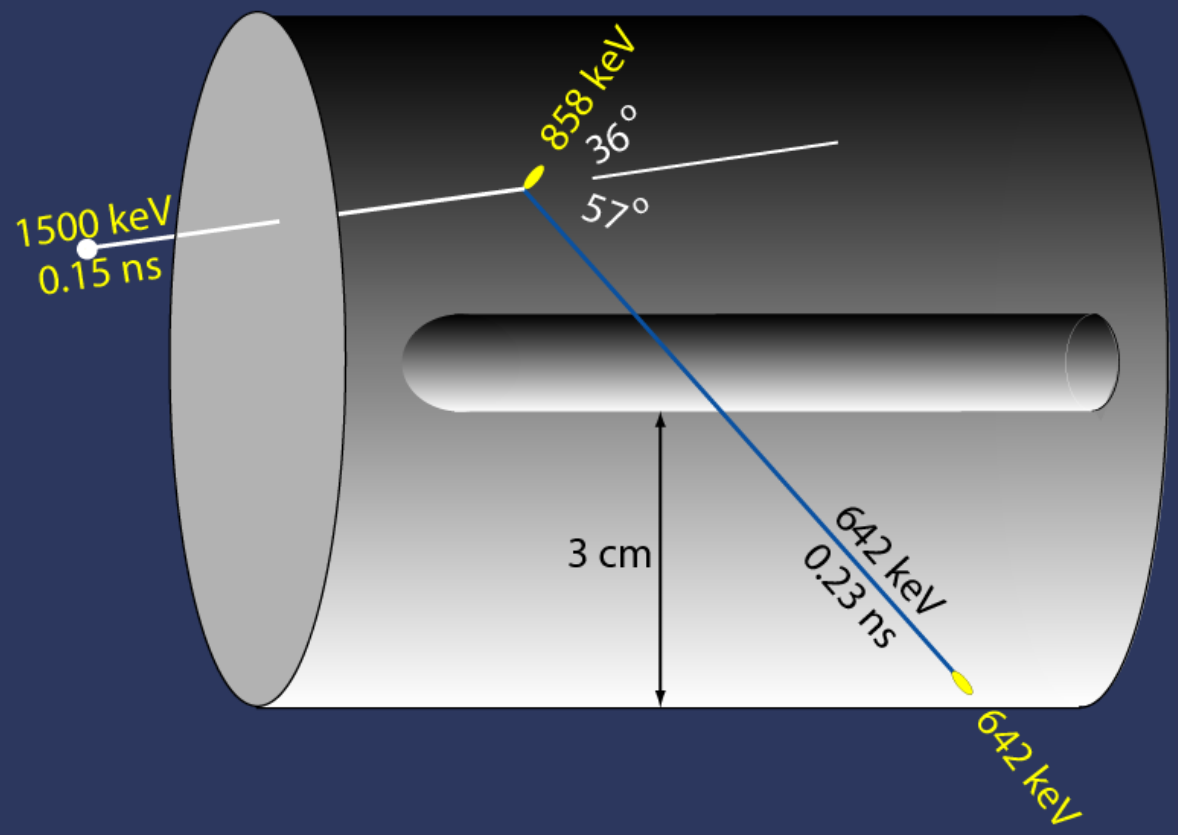
VGSL

ISOCS, LabSOCS

FOI


Part 2 of 2
30.06 h
165 69 Tm
QEC=1592.5
165 68 Er


Part 1 of 2
30.06 h
165 69 Tm
QEC=1592.5
165 68 Er



p-type cylindrical crystal, positive on the mantle and negative on the inner surface

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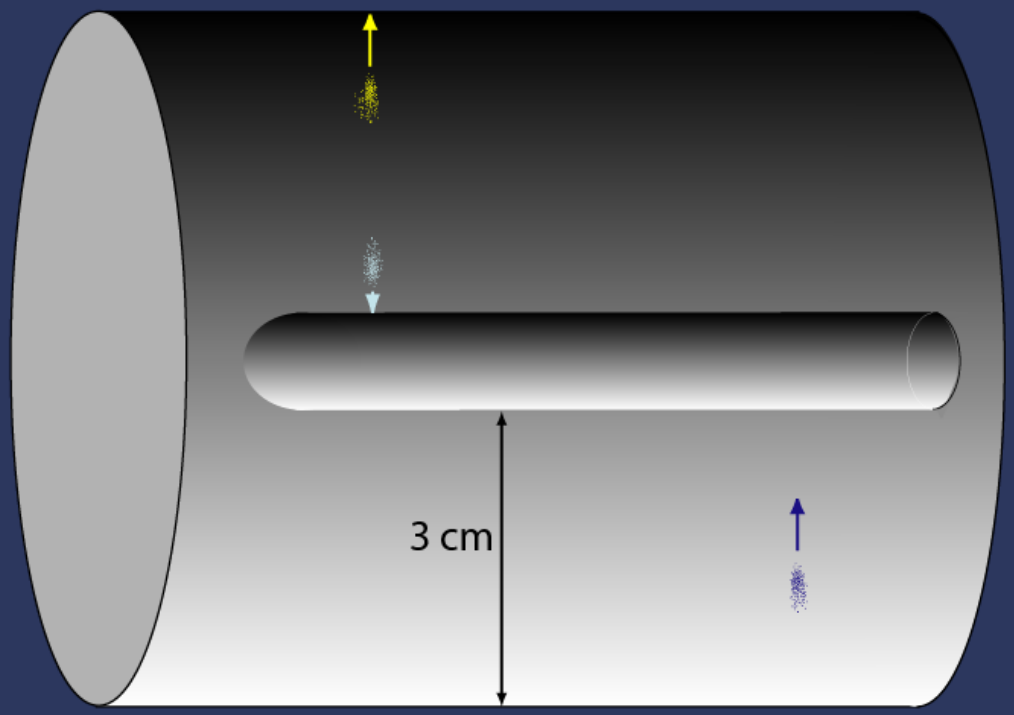
120 ns later



Saturated drifting velocities for both holes and electrons around 7.5 cm per μs imply a preamplifier rise time of about 400 ns. About 300 000 and 200 000 secondary electrons drift towards the mantle and the same number of holes drift towards the center hole [sic].

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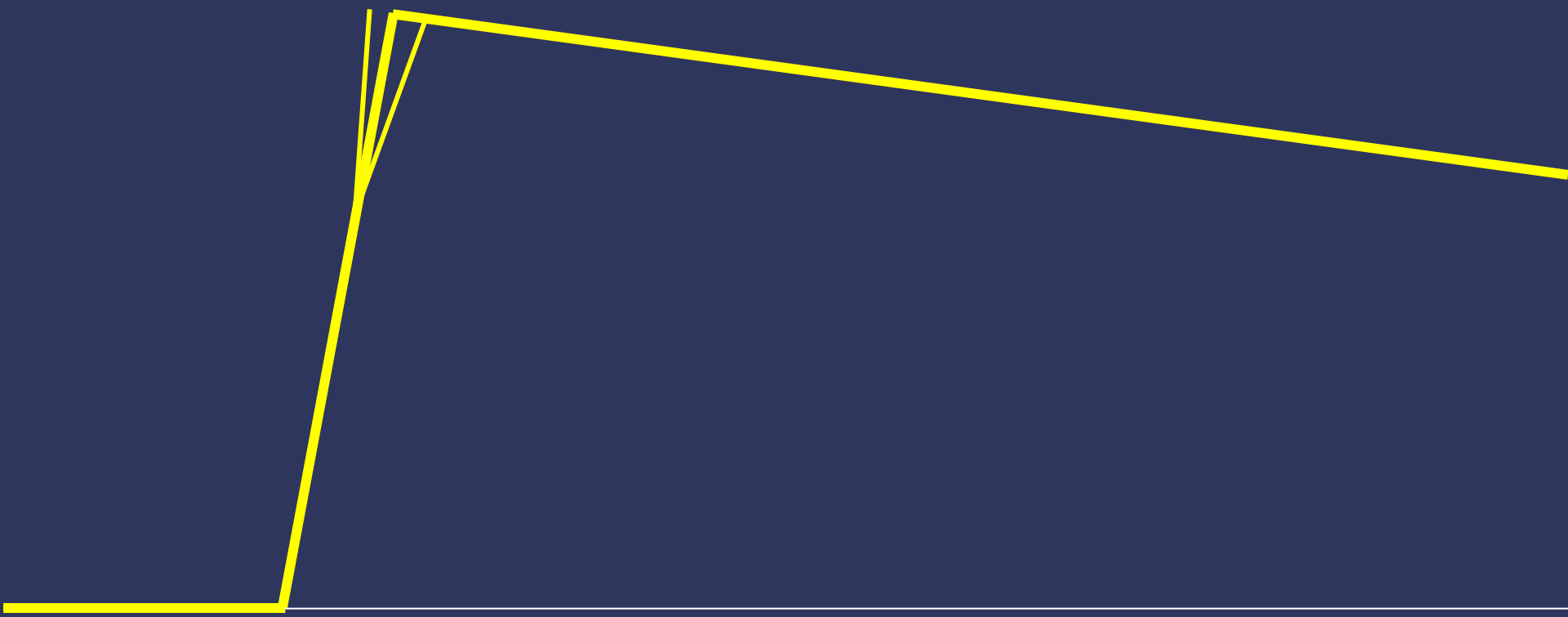

400 ns

50 000 – 150 000 ns

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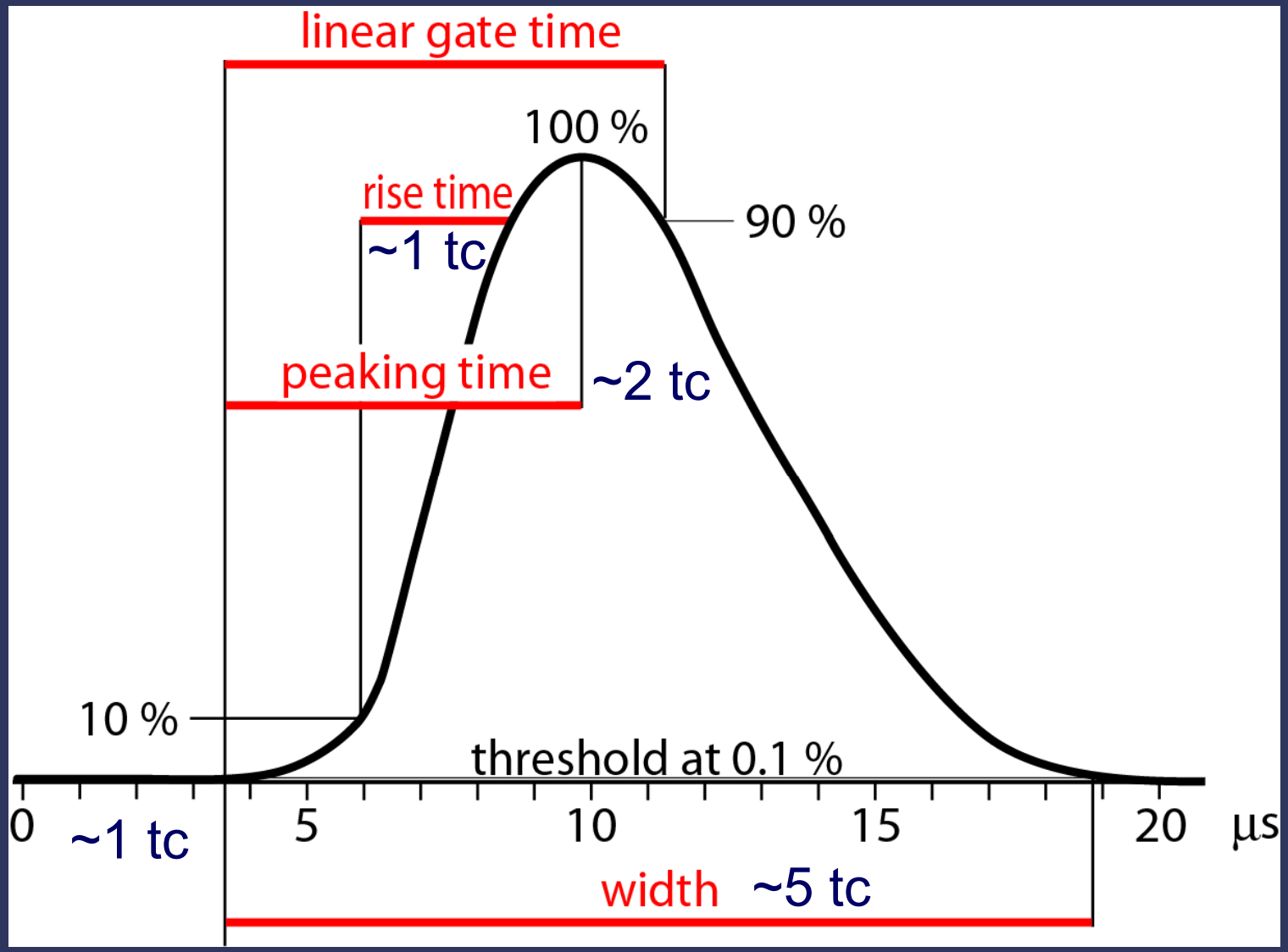
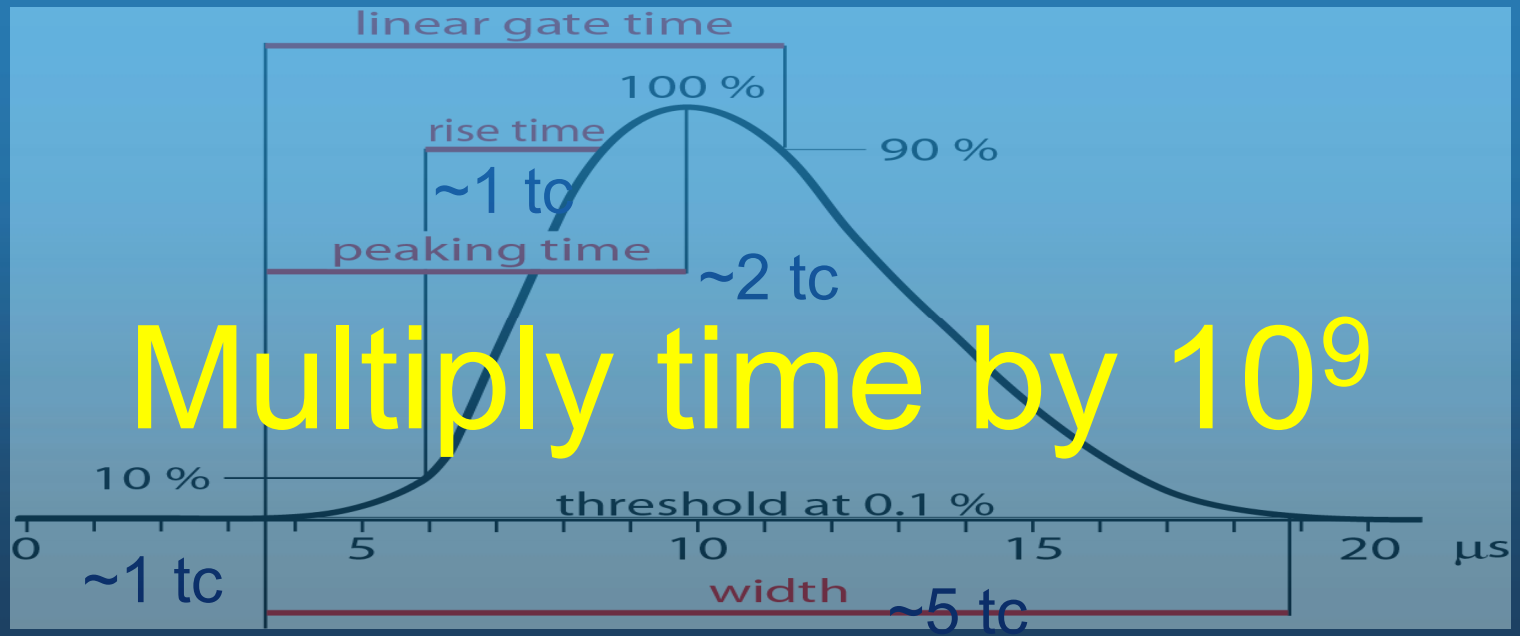


Time constant tc = 3 µs



Multiply time by 10^9

Everything nuclear happened in a 1 sec flash at breakfast this morning

Charge collection finished after eating a sandwich for less than 10 minutes

The useful part of the main amplifier pulse will be ready by lunch time

The ADC will deliver the count to the spectrum late tonight

At 10 cps we can expect next event in November 2013

At 100 cps we can expect next event in mid-February next year.

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Time constant tc = 3 µs


VIRTUAL GAMMA SPETROSCOPY LABORATORY
Acquisition Source Set-up Detector Shielding Source Geometry Material Resolution Refresh time Settings
Welcome to
VGSL
THE VIRTUAL GAMMA SPECTROSCOPY LABORATORY

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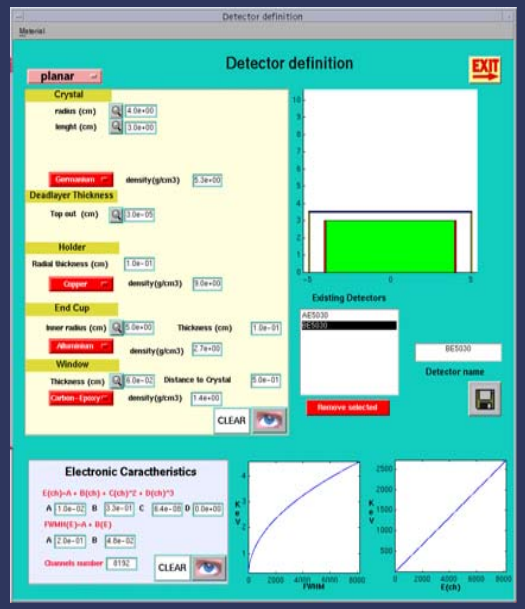
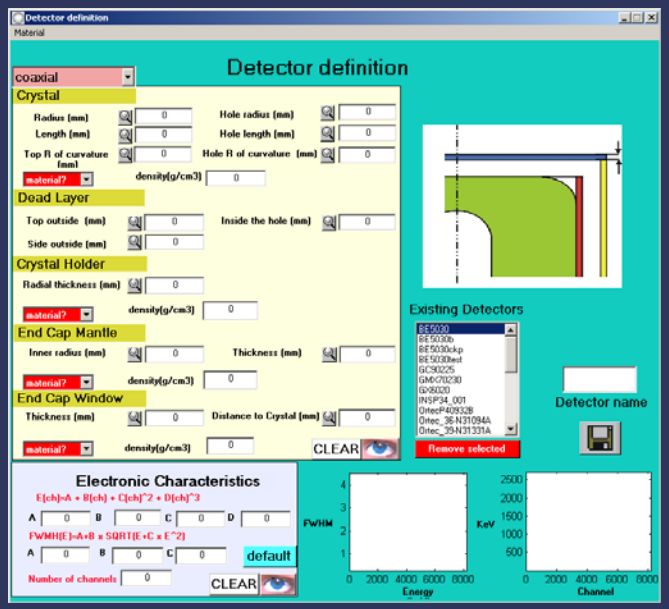
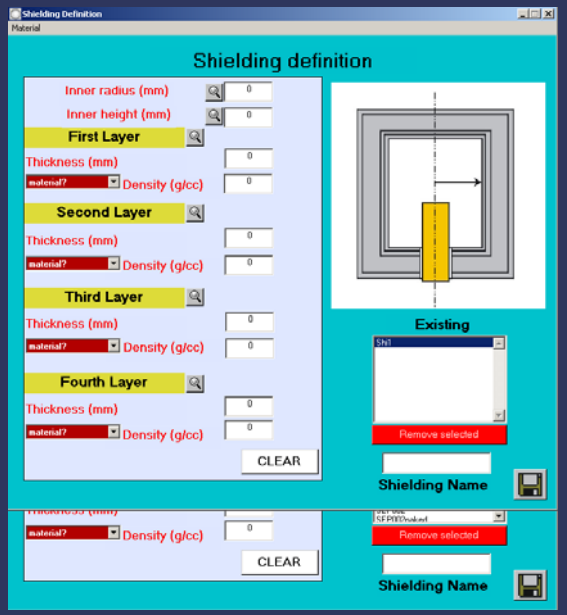
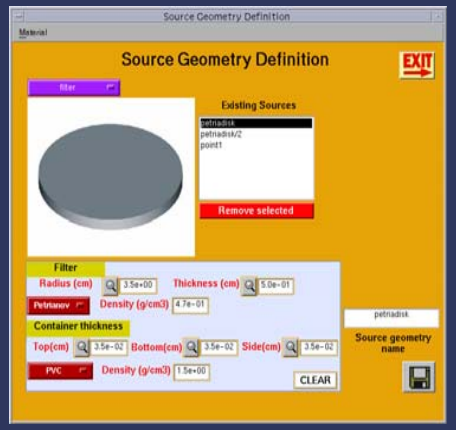
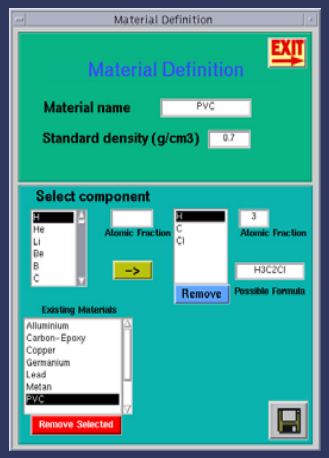
Investing in the laboratory



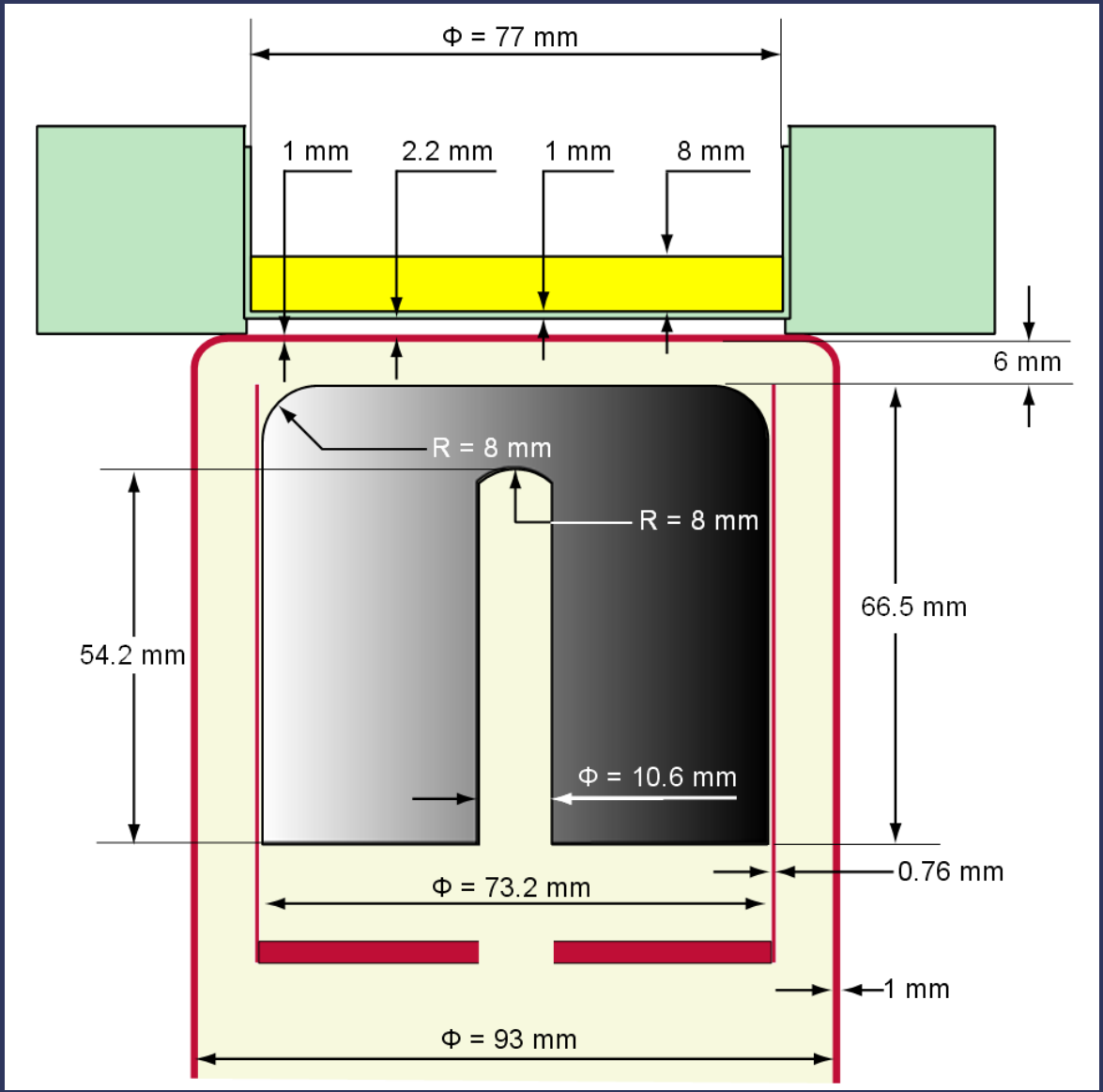




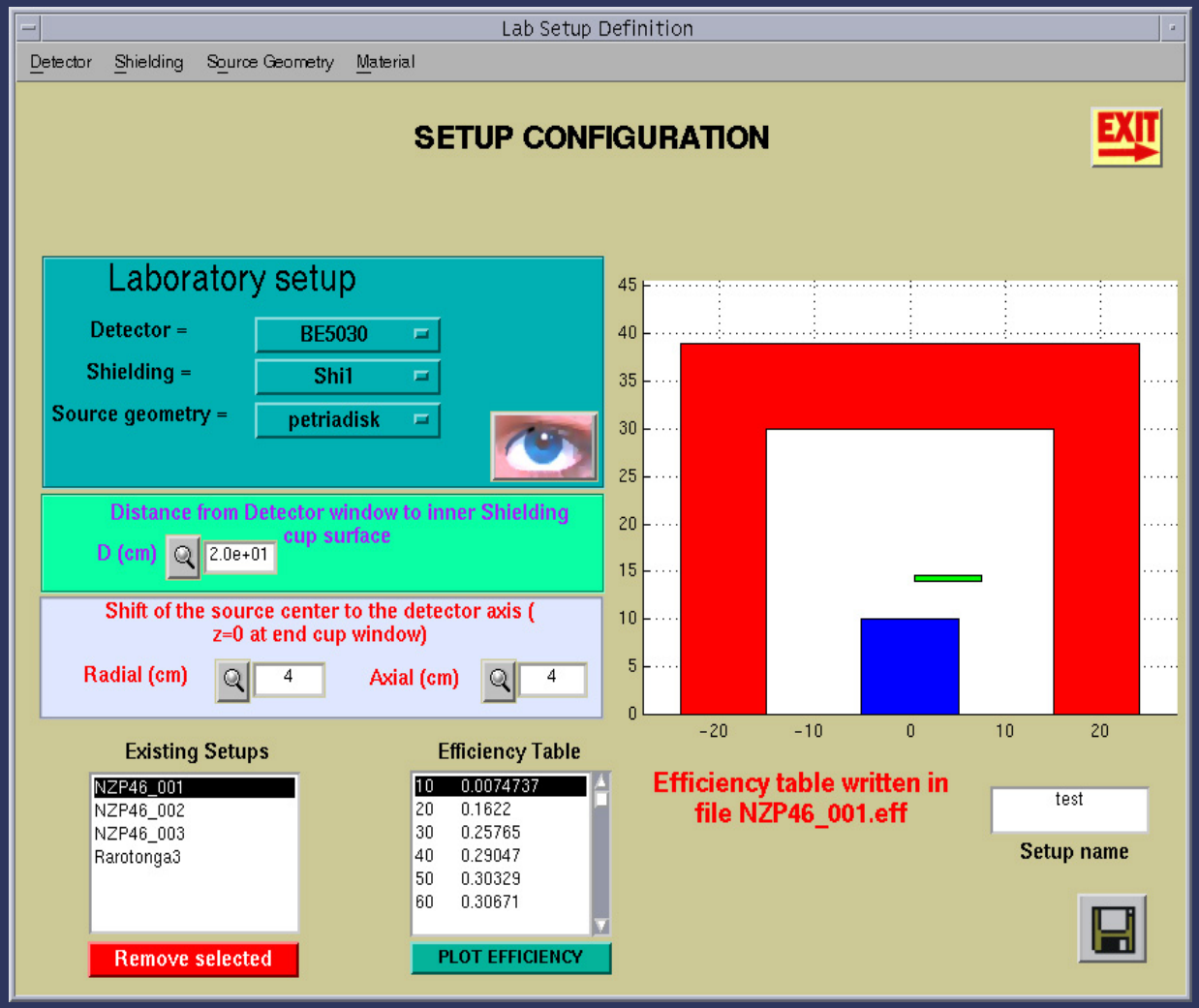




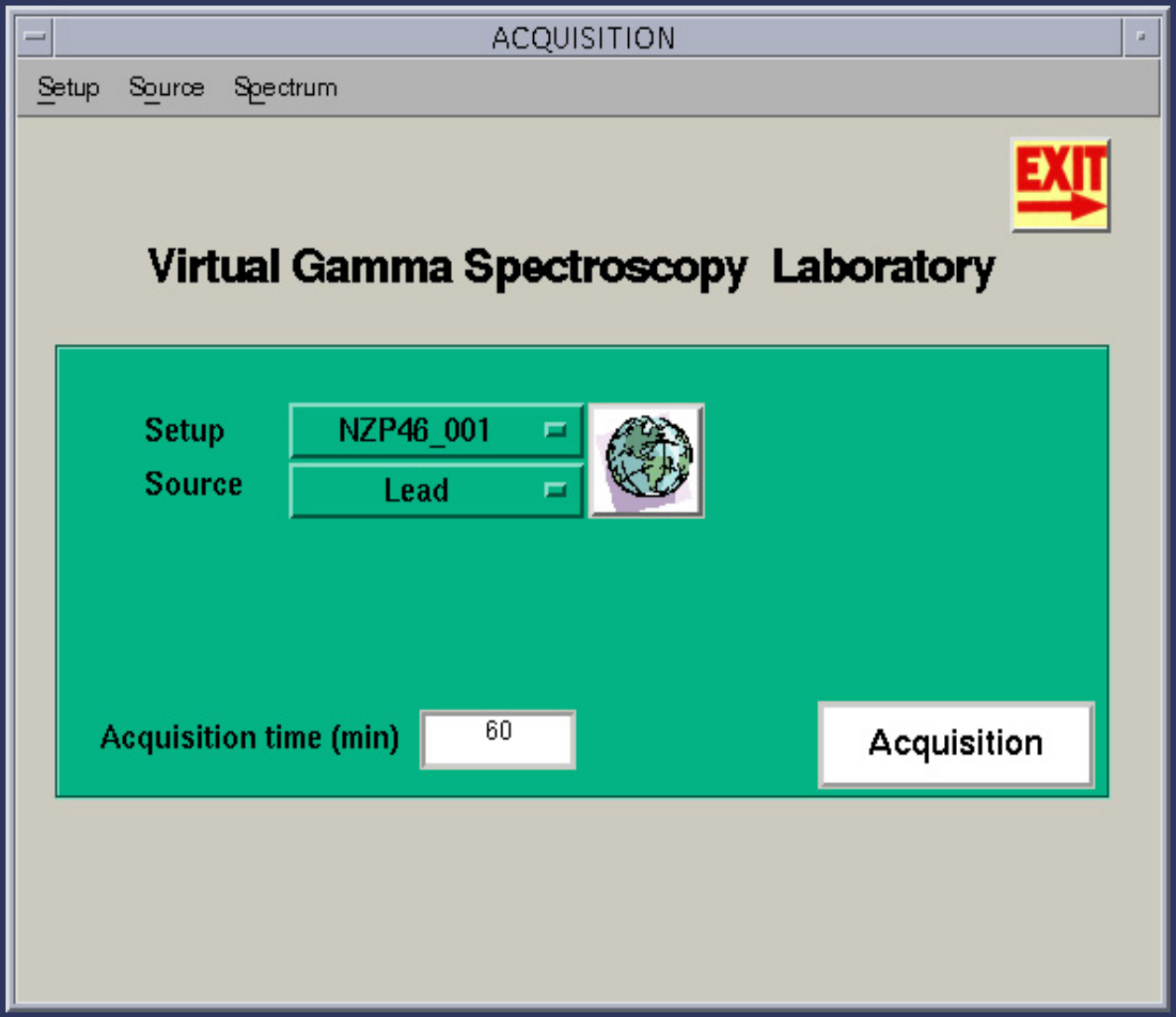
FOI


Φ = 77 mm
1 mm
2.2 mm
1 mm
8 mm
6 mm
R = 8 mm
R = 8 mm
66.5 mm
54.2 mm
Φ = 10.6 mm
0.76 mm
Φ = 73.2 mm
1 mm
Φ = 93 mm

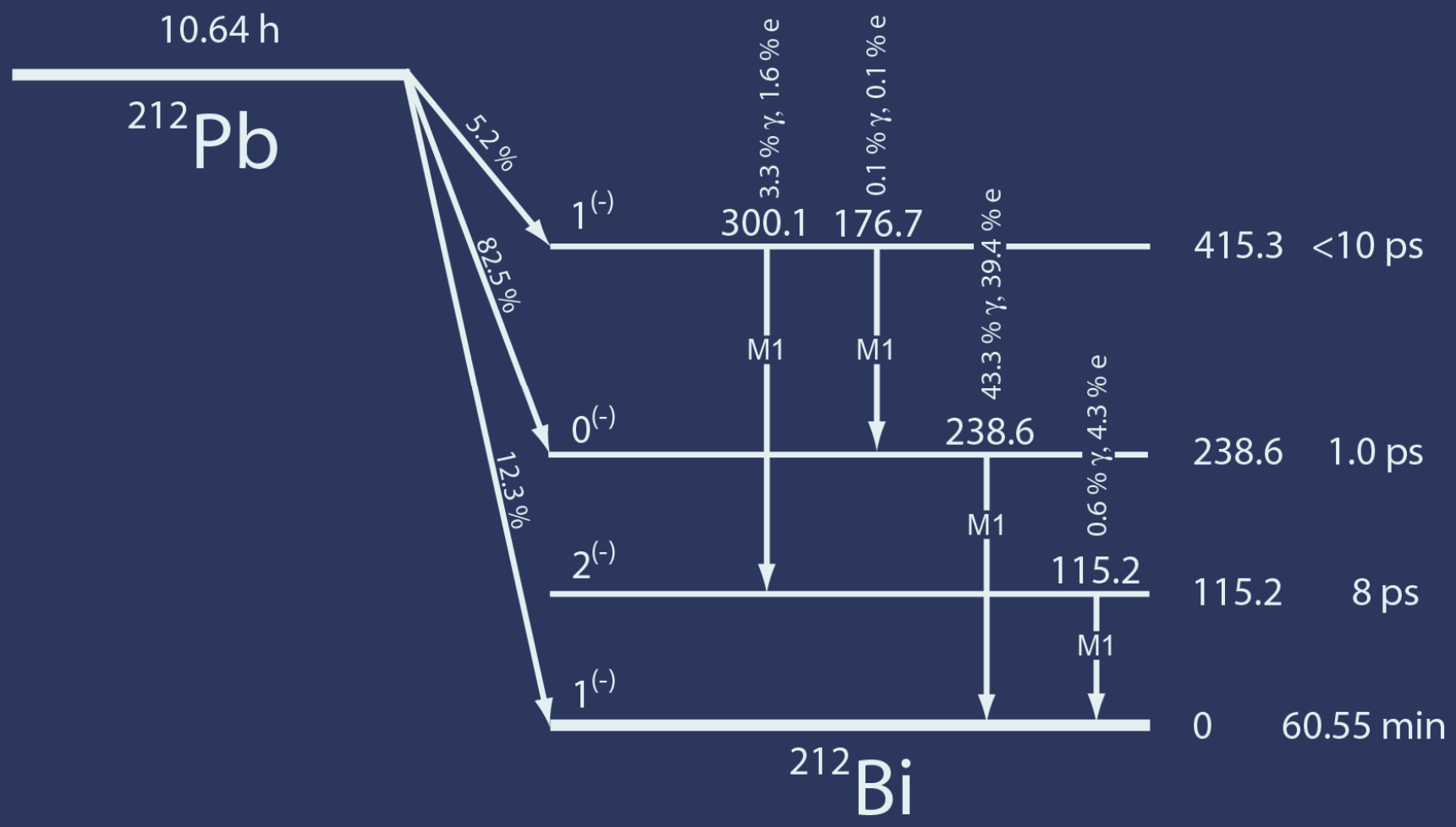
FOI


Lab Setup Definition
Detector
Shielding
Source Geometry
Material
SETUP CONFIGURATION
EXIT
Laboratory setup
Detector =
BE5030
Shielding =
Shi1
Source geometry =
petriadisk
Distance from Detector window to inner Shielding cup surface
D (cm)
2.0e+01
Shift of the source center to the detector axis (z=0 at end cup window)
Radial (cm)
4
Axial (cm)
4
45
40
35
30
25
20
15
10
5
0
-20
-10
0
10
20
Existing Setups
NZP46_001
NZP46_002
NZP46_003
Rarotonga3
Remove selected
Efficiency Table
10 0.0074737
20 0.1622
30 0.25765
40 0.29047
50 0.30329
60 0.30671
PLOT EFFICIENCY
Efficiency table written in file NZP46_001.eff
test
Setup name

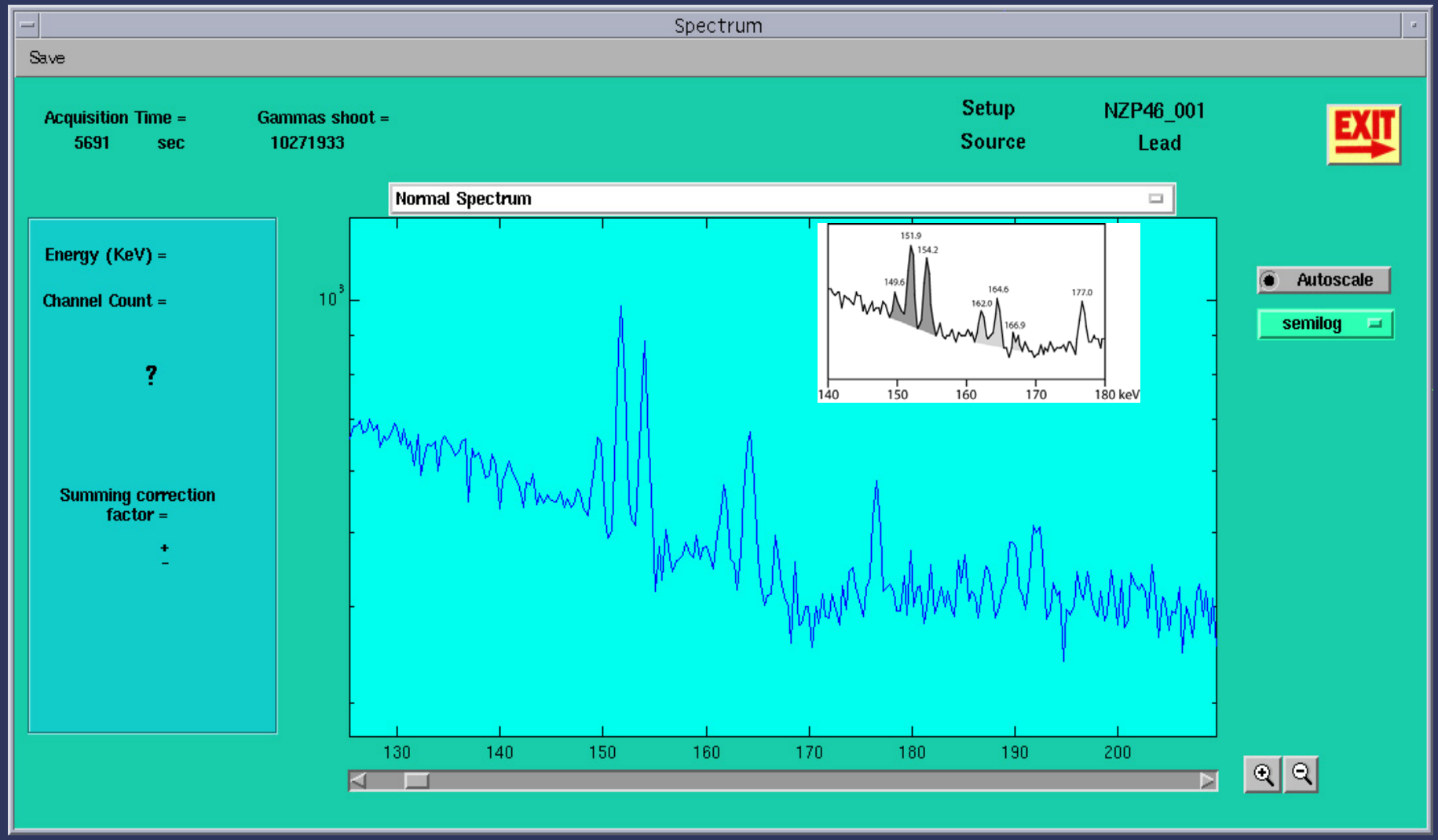
FOI


ACQUISITION
Setup
Source
Spectrum
EXIT
Virtual Gamma Spectroscopy Laboratory
Setup
NZP46_001
Source
Lead
Acquisition time (min)
60
Acquisition

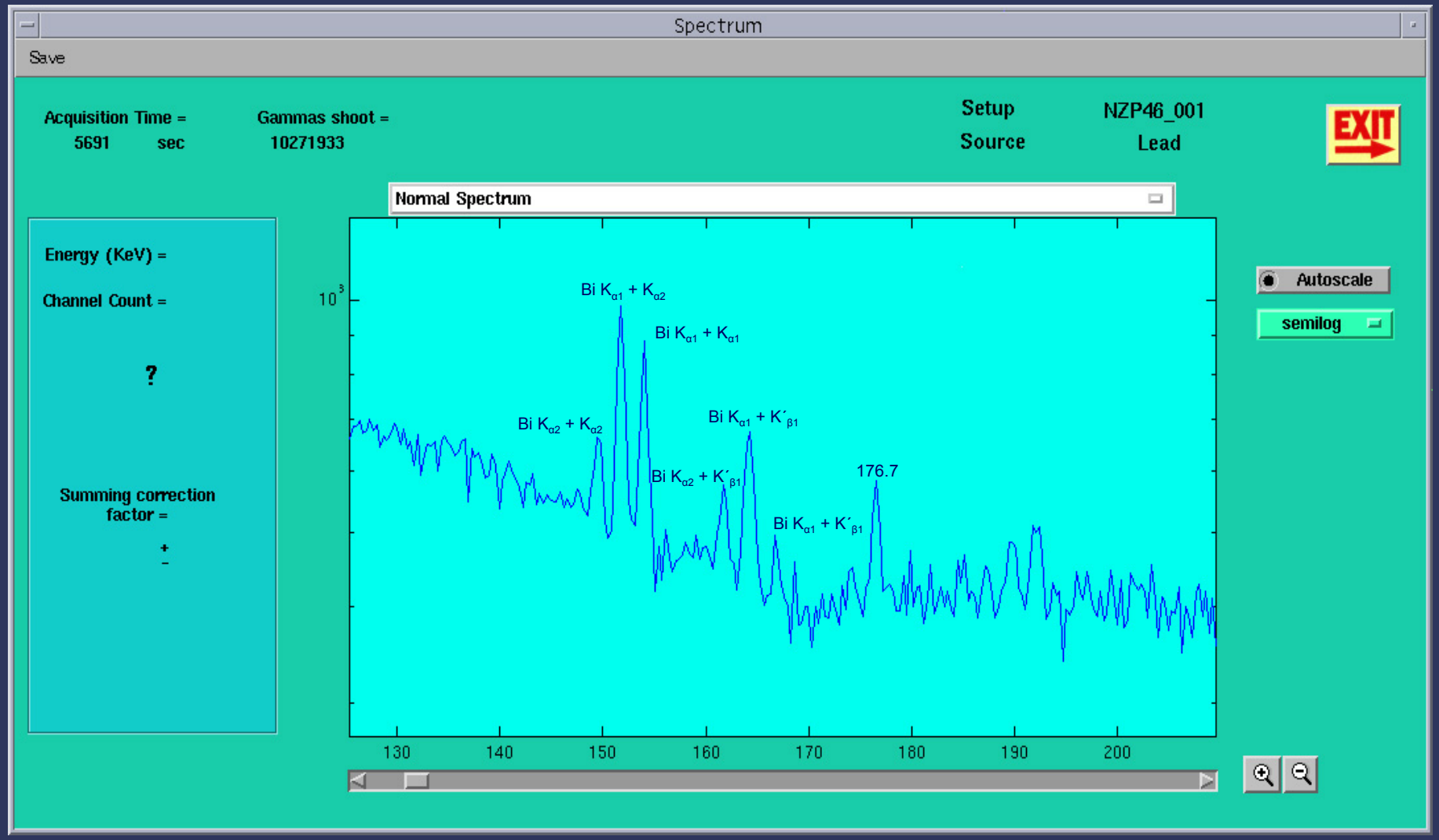
FOI


10.64 h
212Pb
5.2 %
82.5 %
12.3 %
1(-)
0(-)
2(-)
1(-)
3.3 % γ, 1.6 % e
0.1 % γ, 0.1 % e
300.1
176.7
43.3 % γ, 39.4 % e
238.6
0.6 % γ, 4.3 % e
115.2
M1
M1
M1
M1
415.3 <10 ps
238.6 1.0 ps
115.2 8 ps
0 60.55 min
212Bi

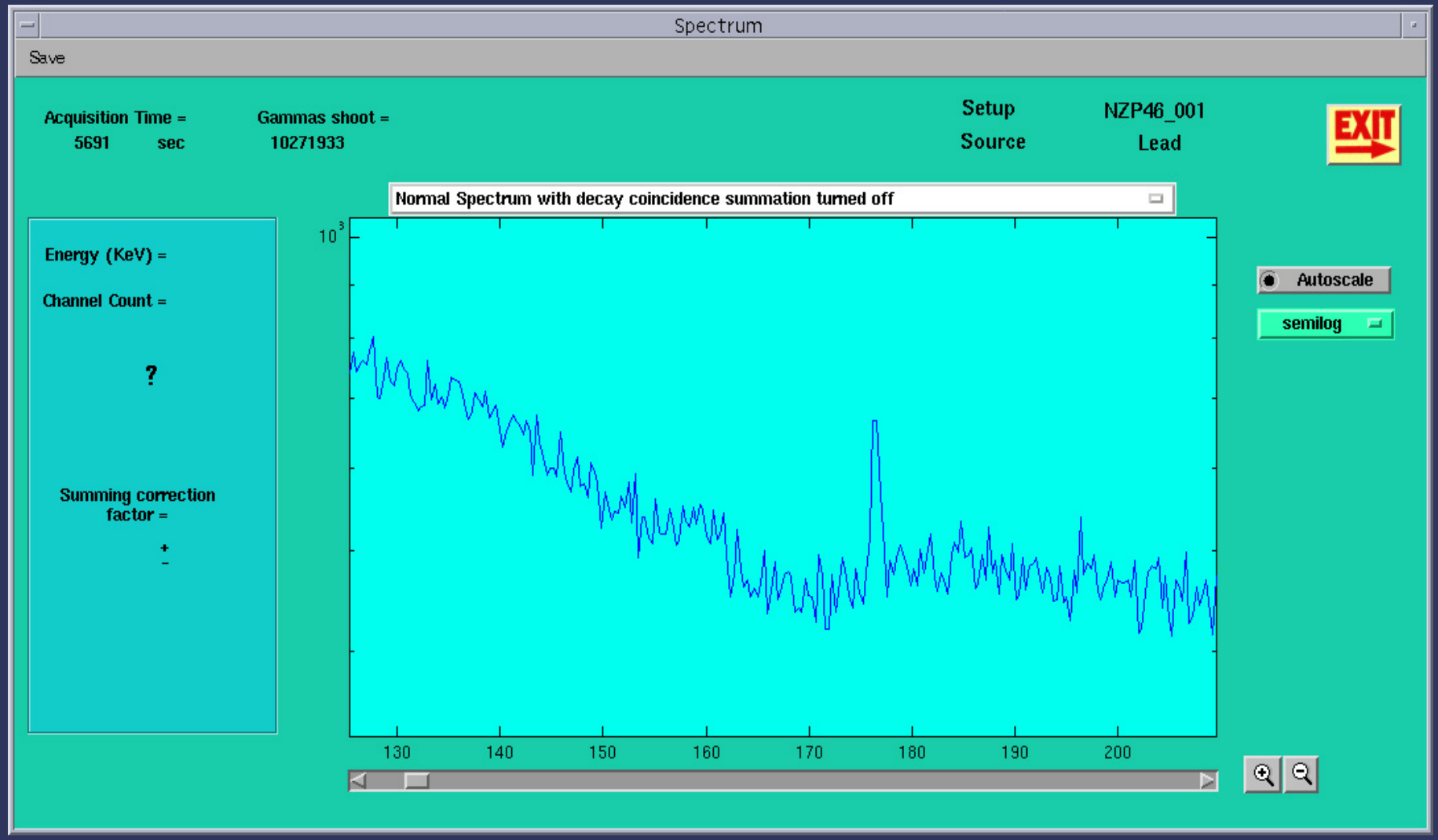
FOI


Spectrum
Save
Acquisition Time =
5691 sec
Gammas shoot =
10271933
Setup
NZP46_001
Source
Lead
EXIT
Normal Spectrum
Energy (KeV) =
Channel Count =
?
Summing correction factor =
+
-
10^3
130
140
150
160
170
180
190
200
151.9
154.2
149.6
164.6
162.0
166.9
177.0
140
150
160
170
180 keV
Autoscale
semilog

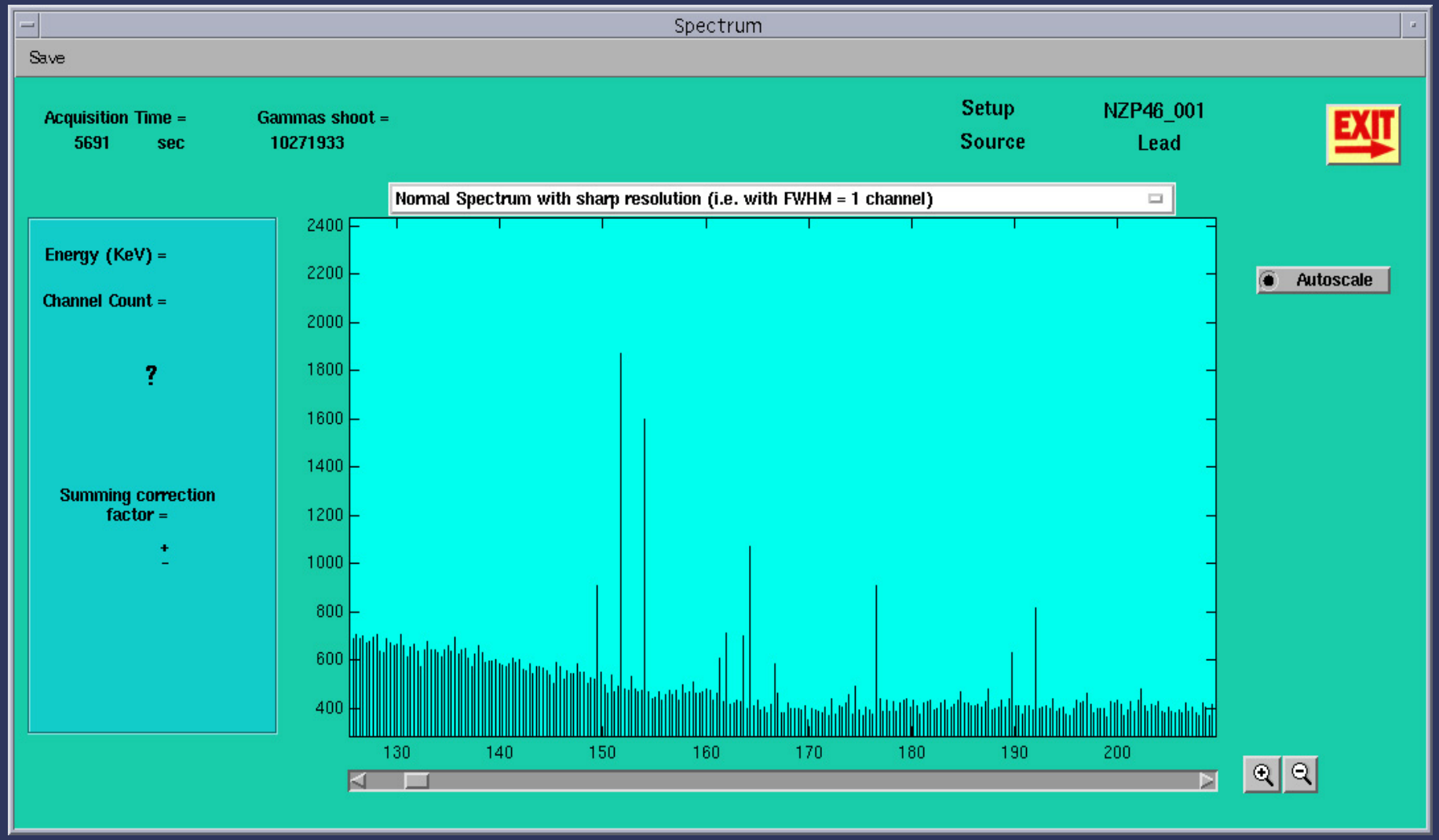
FOI


Spectrum
Save
Acquisition Time =
5691 sec
Gammas shoot =
10271933
Setup
NZP46_001
Source
Lead
EXIT
Normal Spectrum
Energy (KeV) =
Channel Count =
?
Summing correction factor =
+
-
10^3
Bi $K_{\alpha1}$ + $K_{\alpha2}$
Bi $K_{\alpha1}$ + $K_{\alpha1}$
Bi $K_{\alpha2}$ + $K_{\alpha2}$
Bi $K_{\alpha1}$ + $K'_{\beta1}$
Bi $K_{\alpha2}$ + $K'_{\beta1}$
176.7
Bi $K_{\alpha1}$ + $K'_{\beta1}$
130
140
150
160
170
180
190
200
Autoscale
semilog

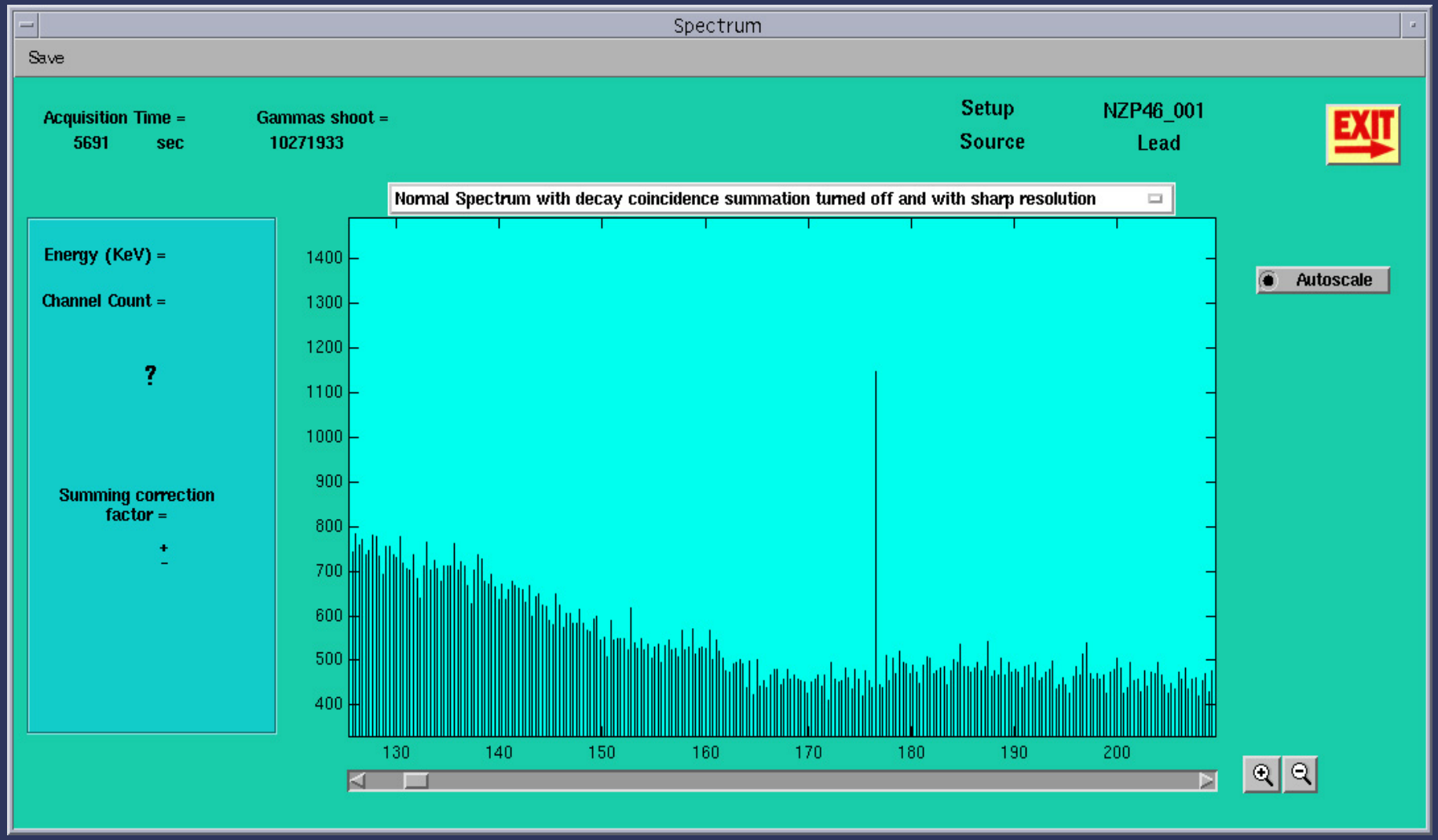
FOI


Spectrum
Save
Acquisition Time =
5691 sec
Gammas shoot =
10271933
Setup
NZP46_001
Source
Lead
EXIT
Normal Spectrum with decay coincidence summation turned off
Energy (KeV) =
Channel Count =
?
Summing correction factor =
+
-
10^3
130
140
150
160
170
180
190
200
Autoscale
semilog

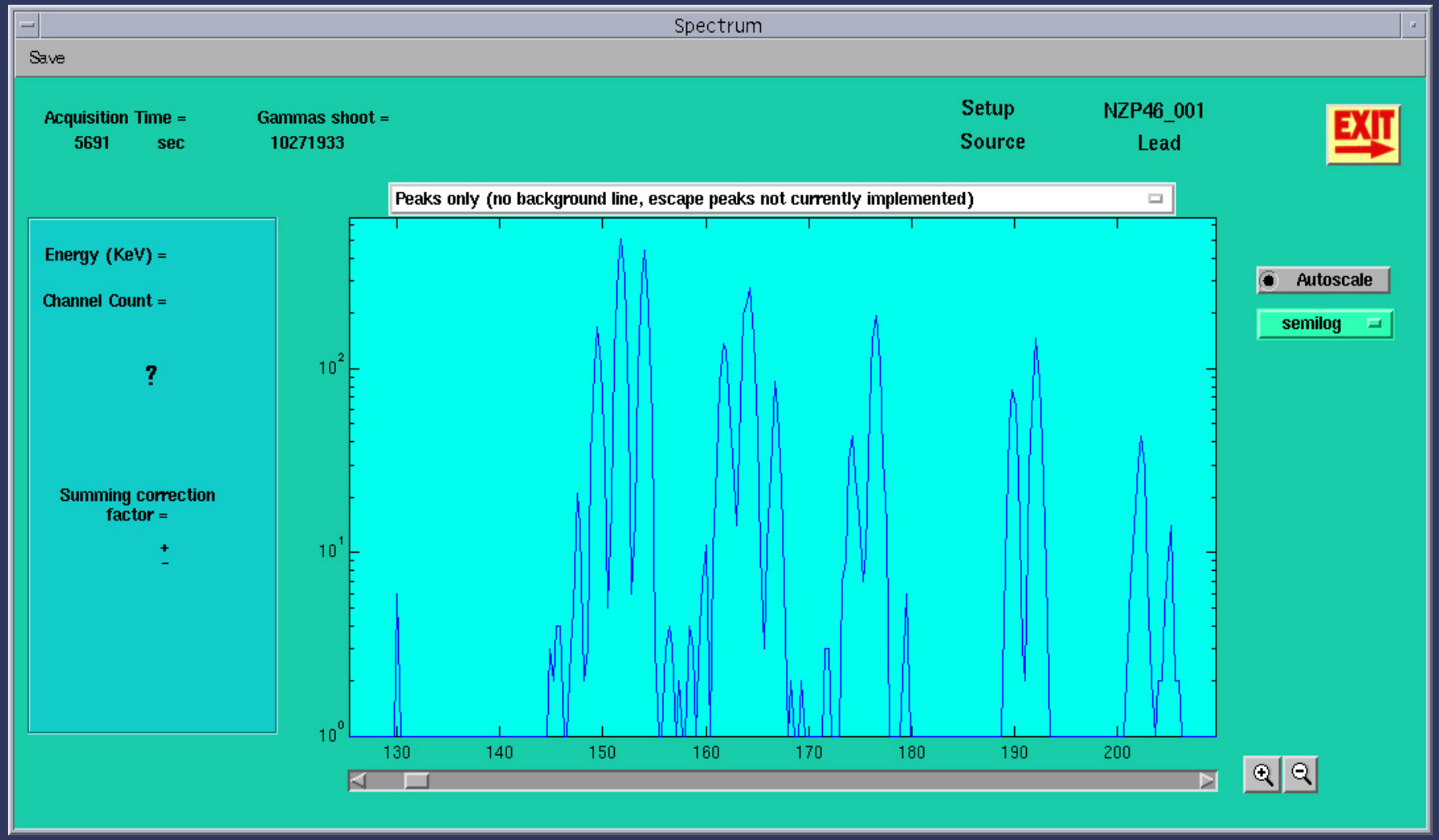
FOI


Spectrum
Save
Acquisition Time =
5691 sec
Gammas shoot =
10271933
Setup
NZP46_001
Source
Lead
EXIT
Normal Spectrum with sharp resolution (i.e. with FWHM = 1 channel)
Energy (KeV) =
Channel Count =
?
Summing correction factor =
+
-
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
130
140
150
160
170
180
190
200
Autoscale

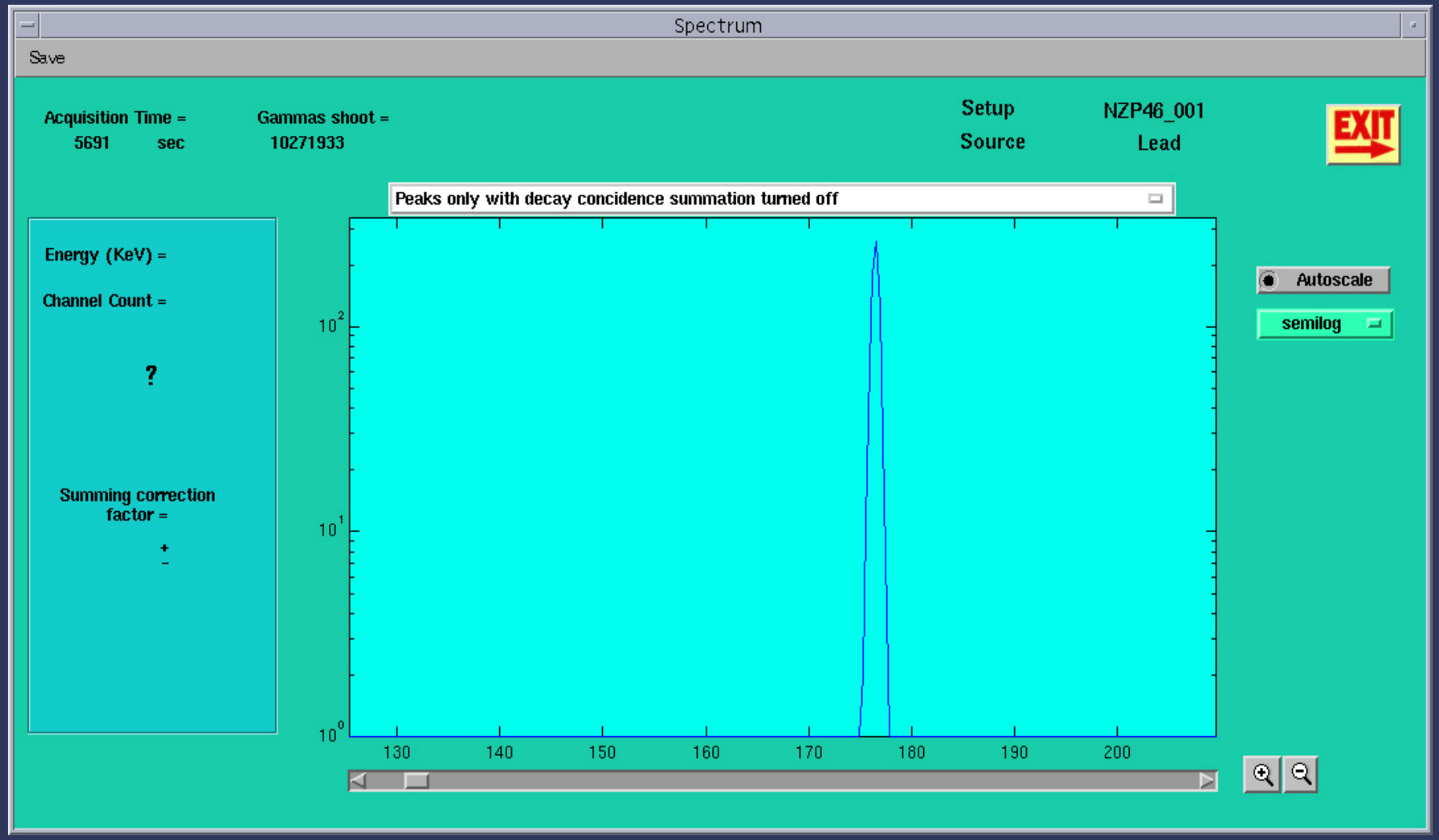
FOI


Spectrum
Save
Acquisition Time =
5691 sec
Gammas shoot =
10271933
Setup
NZP46_001
Source
Lead
EXIT
Normal Spectrum with decay coincidence summation turned off and with sharp resolution
Energy (KeV) =
Channel Count =
?
Summing correction factor =
+
-
1400
1300
1200
1100
1000
900
800
700
600
500
400
130
140
150
160
170
180
190
200
Autoscale

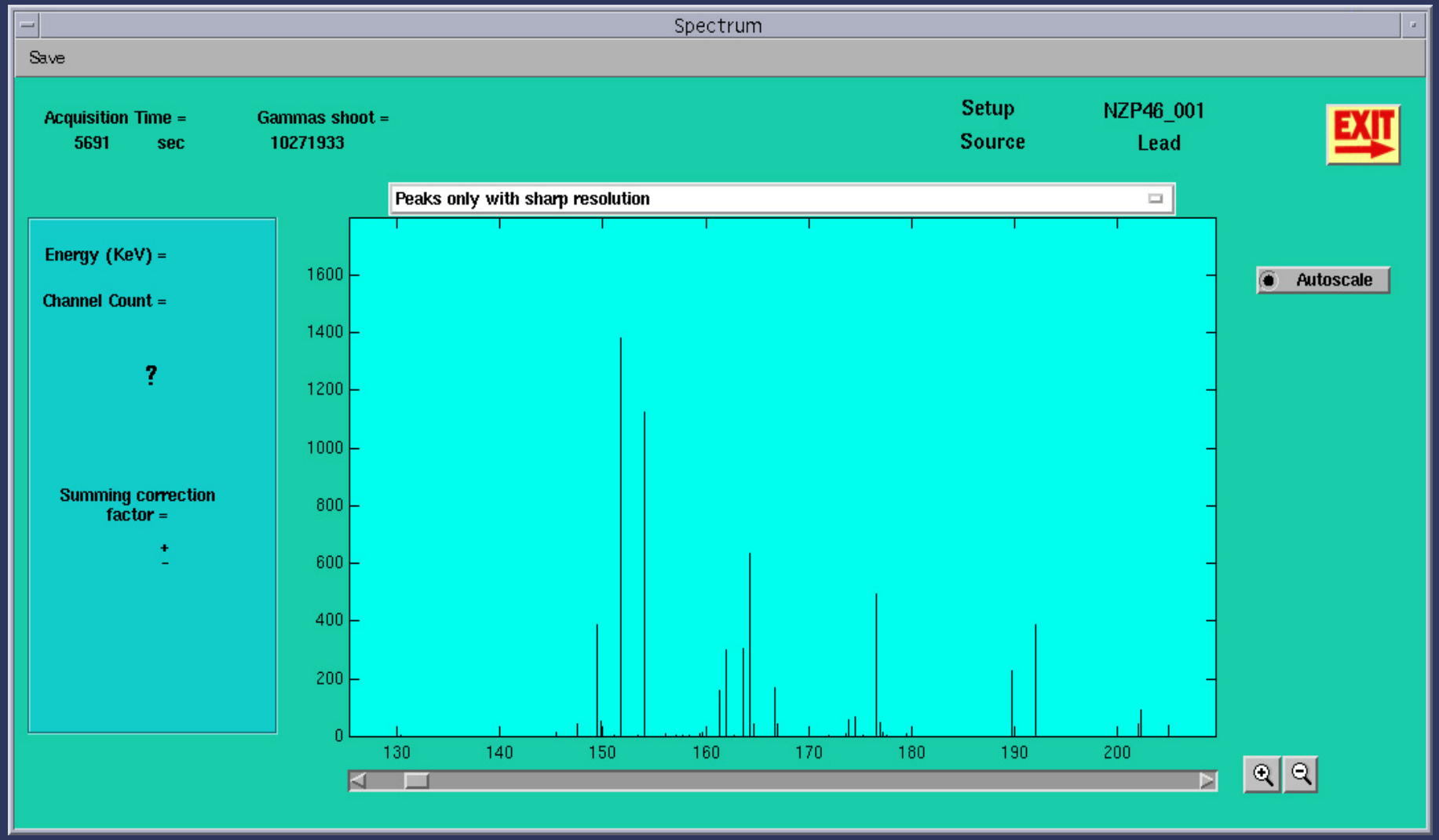
FOI


Spectrum
Save
Acquisition Time =
5691 sec
Gammas shoot =
10271933
Setup
NZP46_001
Source
Lead
EXIT
Peaks only (no background line, escape peaks not currently implemented)
Energy (KeV) =
Channel Count =
?
Summing correction factor =
+
-
Autoscale
semilog
10^2
10^1
10^0
130
140
150
160
170
180
190
200

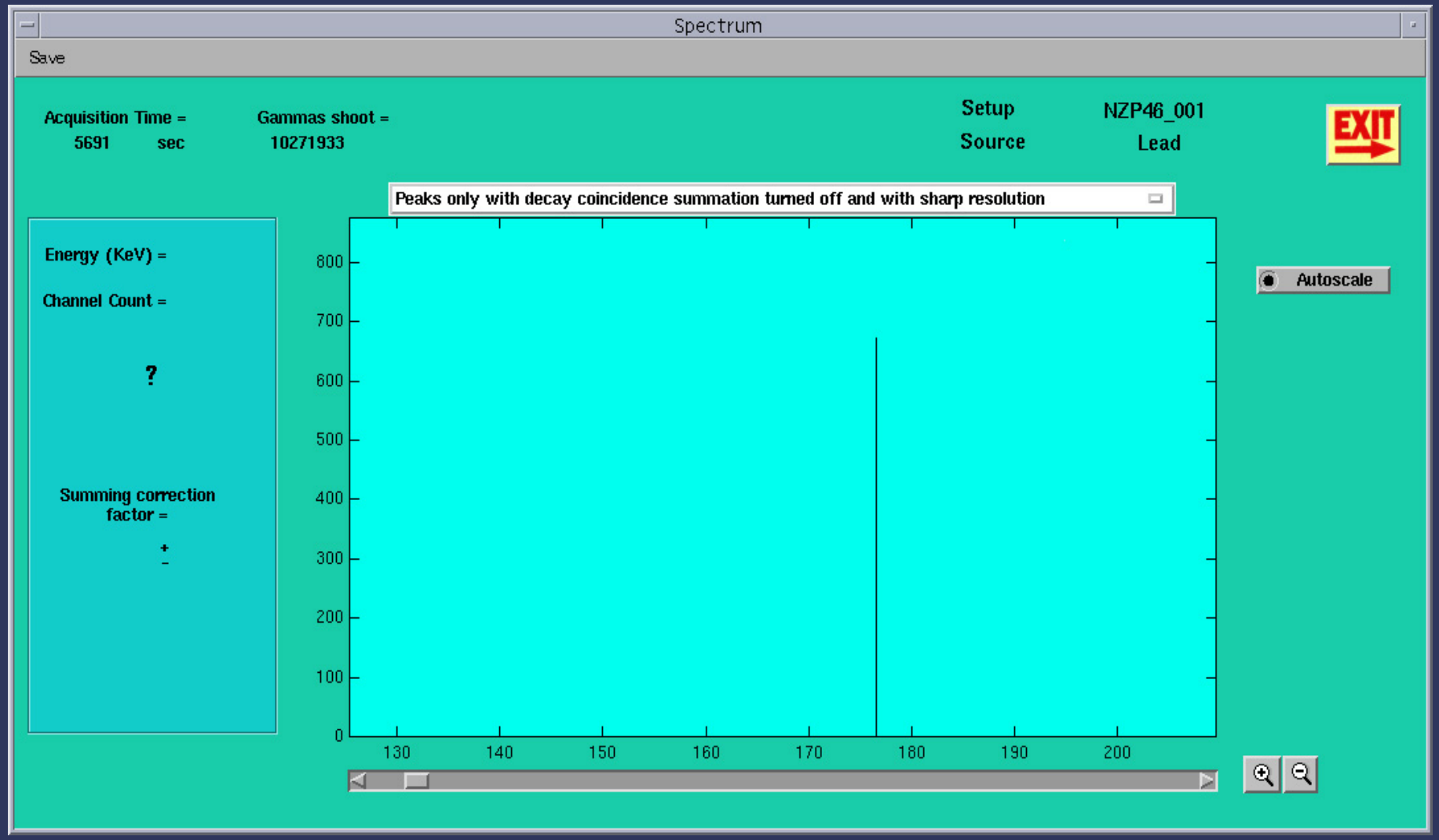
FOI


Spectrum
Save
Acquisition Time =
5691 sec
Gammas shoot =
10271933
Setup
NZP46_001
Source
Lead
EXIT
Peaks only with decay concidence summation turned off
Energy (KeV) =
Channel Count =
?
Summing correction factor =
+
-
Autoscale
semilog
10^2
10^1
10^0
130
140
150
160
170
180
190
200

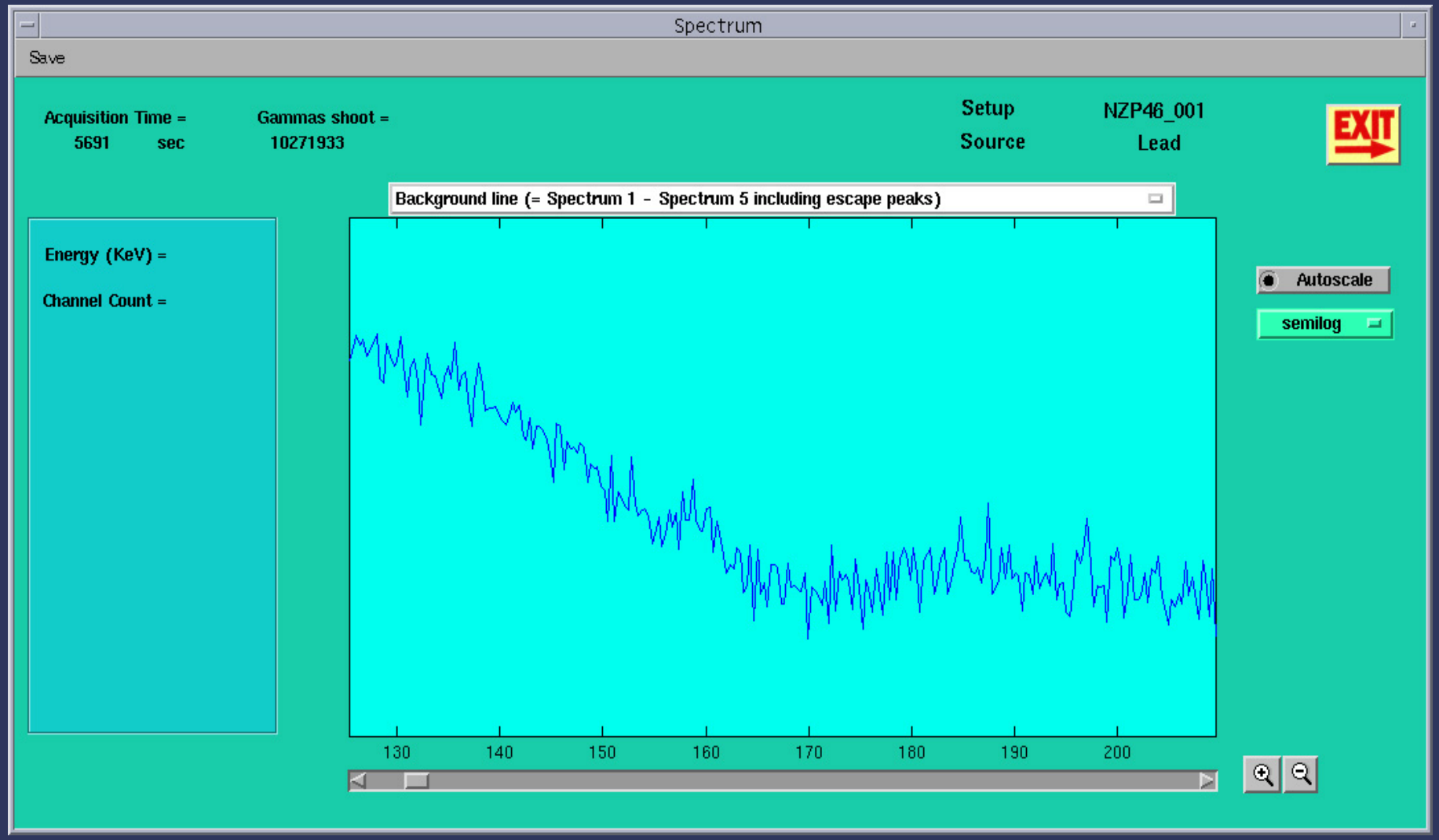
FOI


Spectrum
Save
Acquisition Time =
5691 sec
Gammas shoot =
10271933
Setup
NZP46_001
Source
Lead
EXIT
Peaks only with sharp resolution
Energy (KeV) =
Channel Count =
?
Summing correction factor =
+
-
1600
1400
1200
1000
800
600
400
200
0
130
140
150
160
170
180
190
200
Autoscale

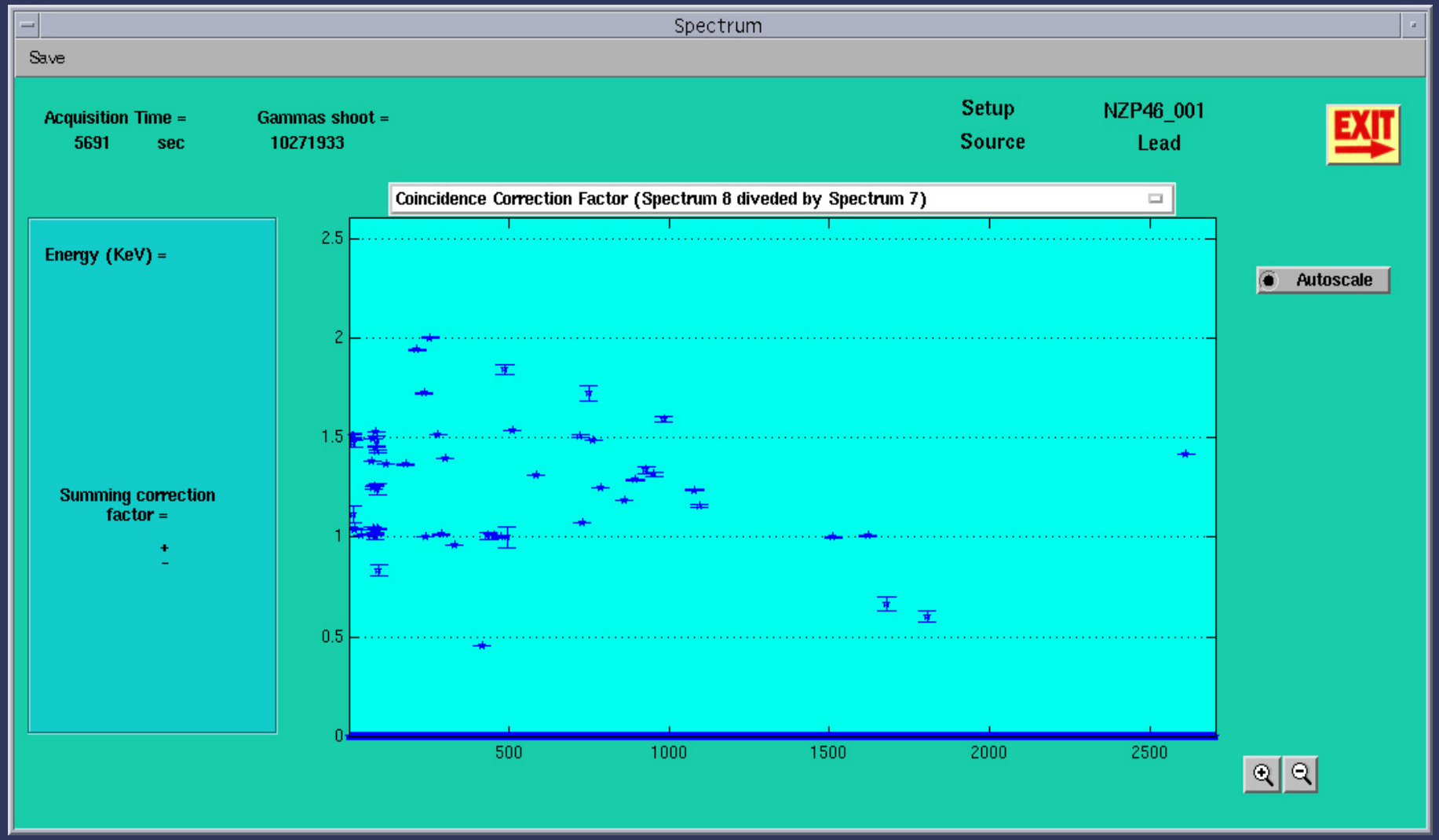
FOI


Spectrum
Save
Acquisition Time =
5691 sec
Gammas shoot =
10271933
Setup
NZP46_001
Source
Lead
EXIT
Peaks only with decay coincidence summation turned off and with sharp resolution
Energy (KeV) =
Channel Count =
?
Summing correction factor =
+
-
800
700
600
500
400
300
200
100
0
130
140
150
160
170
180
190
200
Autoscale

FOI

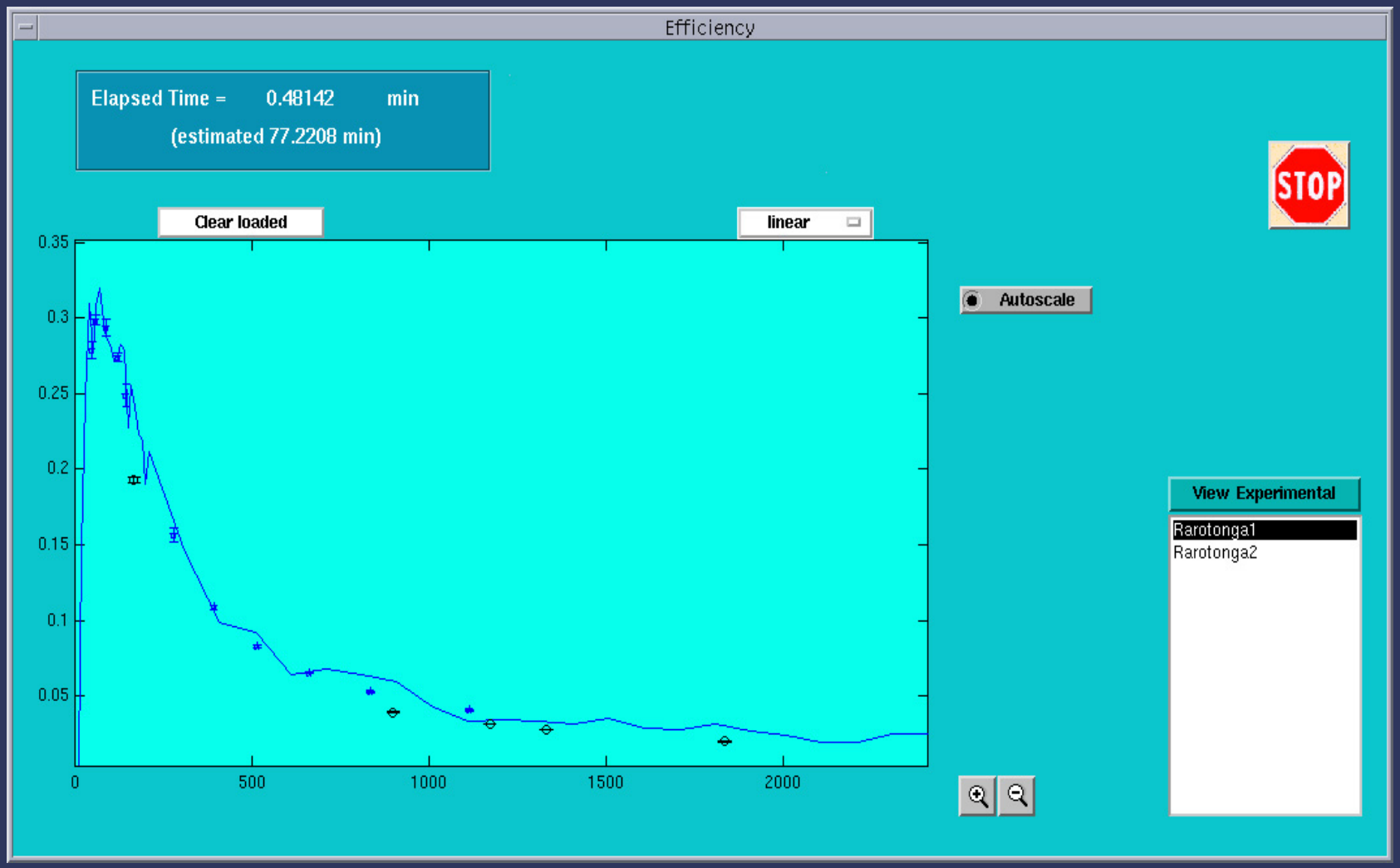

Spectrum
Save
Acquisition Time =
5691 sec
Gammas shoot =
10271933
Setup
NZP46_001
Source
Lead
EXIT
Background line (= Spectrum 1 - Spectrum 5 including escape peaks)
Energy (KeV) =
Channel Count =
Autoscale
semilog
130
140
150
160
170
180
190
200

FOI


Spectrum
Save
Acquisition Time =
5691 sec
Gammas shoot =
10271933
Setup
NZP46_001
Source
Lead
EXIT
Coincidence Correction Factor (Spectrum 8 diveded by Spectrum 7)
Energy (KeV) =
Summing correction factor =
+
-
2.5
2
1.5
1
0.5
0
500
1000
1500
2000
2500
Autoscale

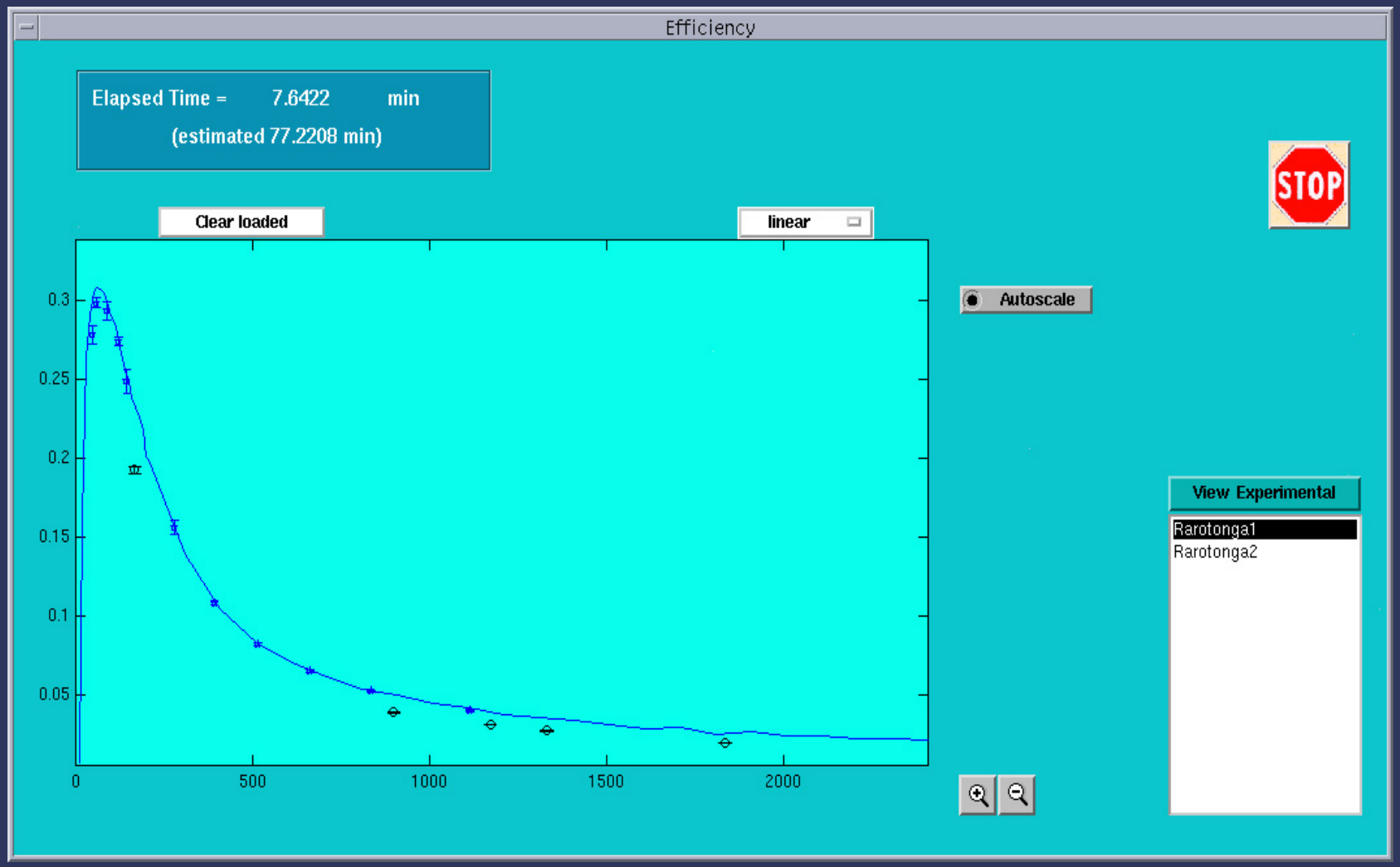
FOI

Efficiency curve after half a minute



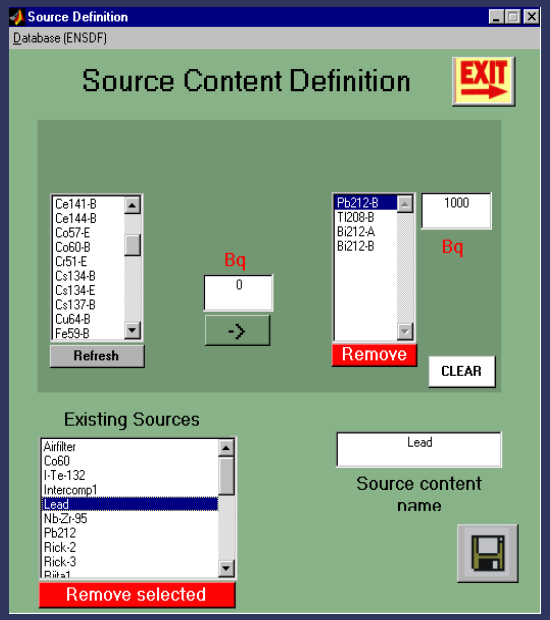
FOI

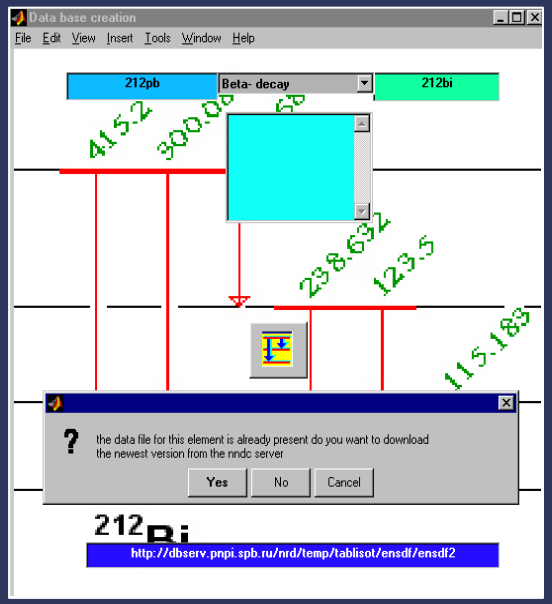
Efficiency curve after 7.6 minutes

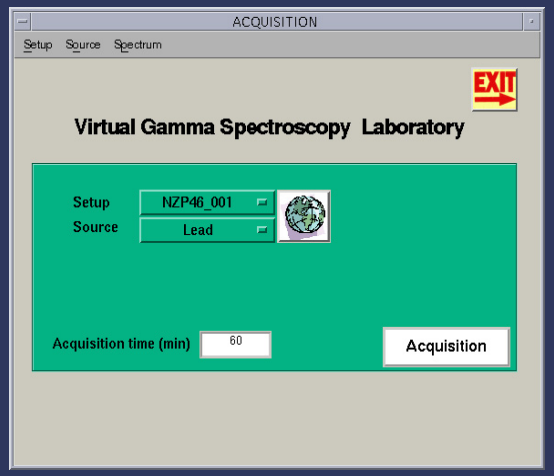


FOI

Running an experiment







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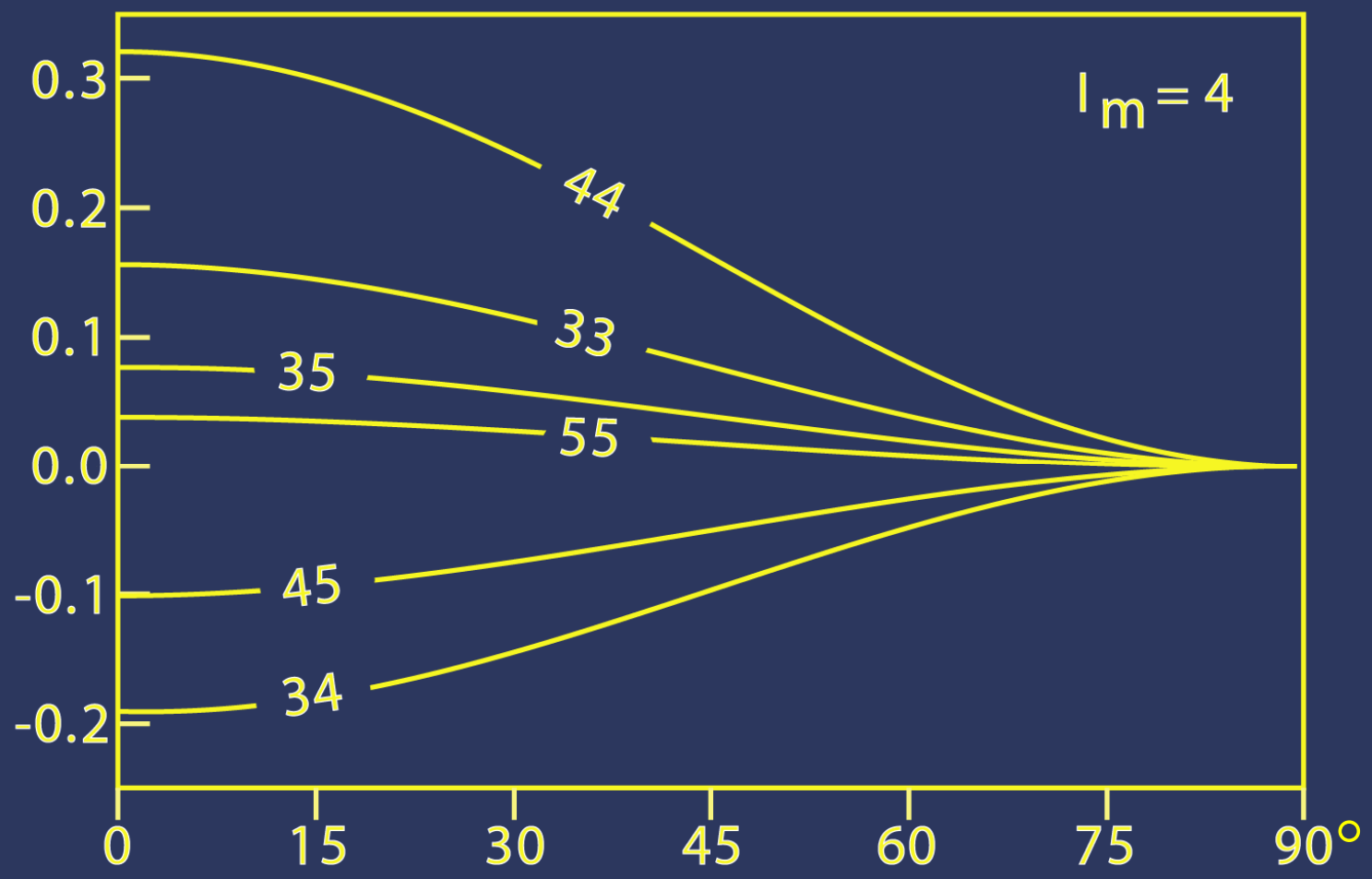
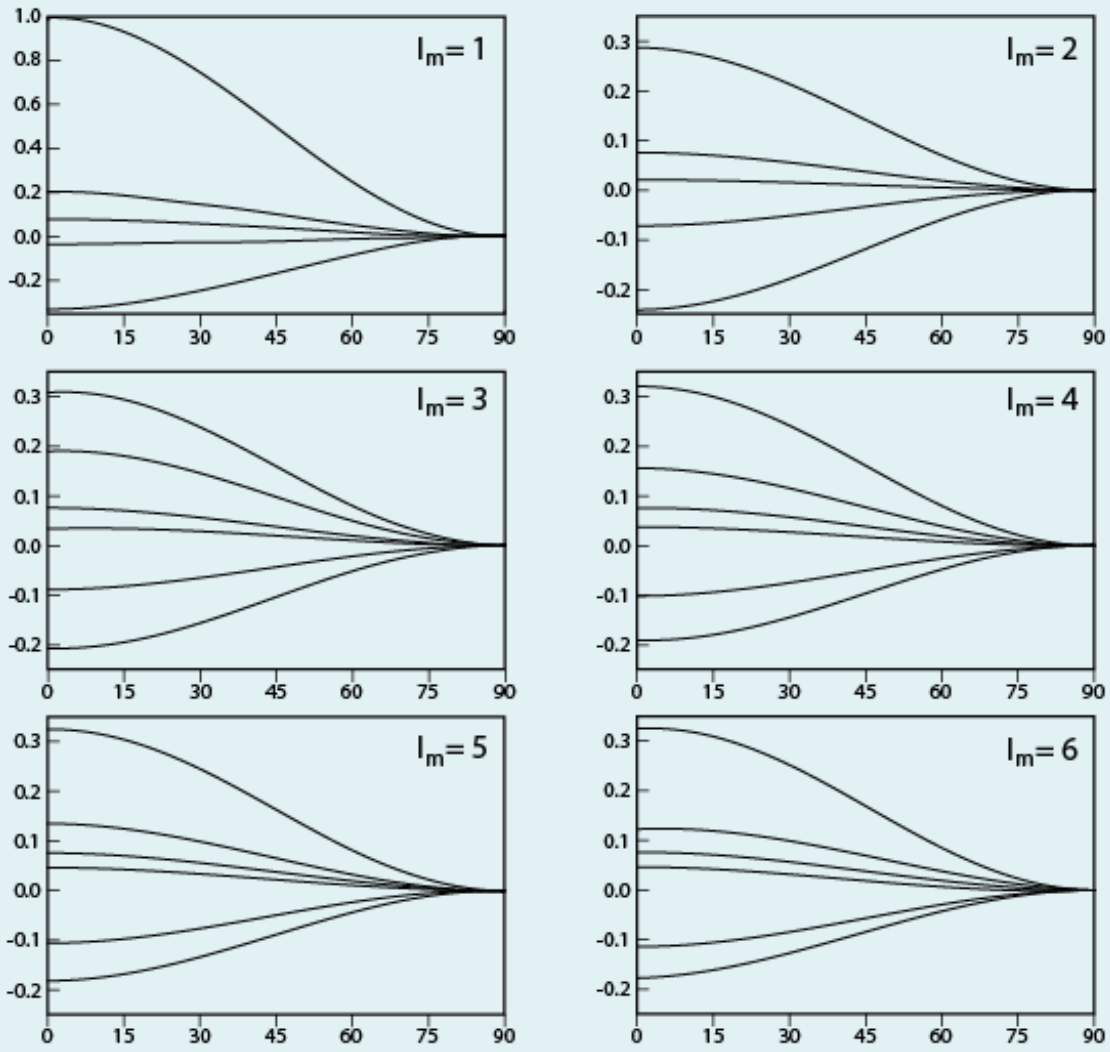


FOI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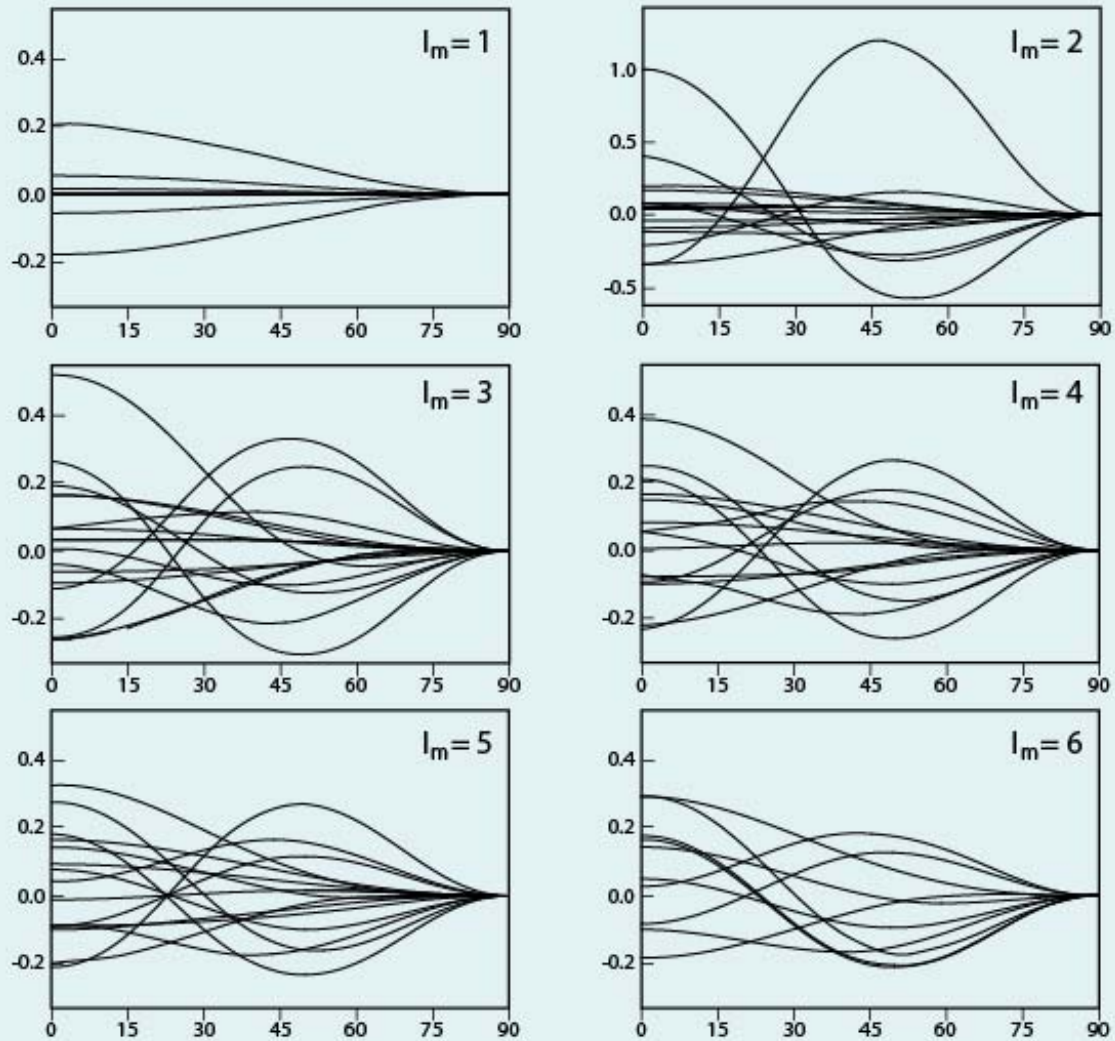
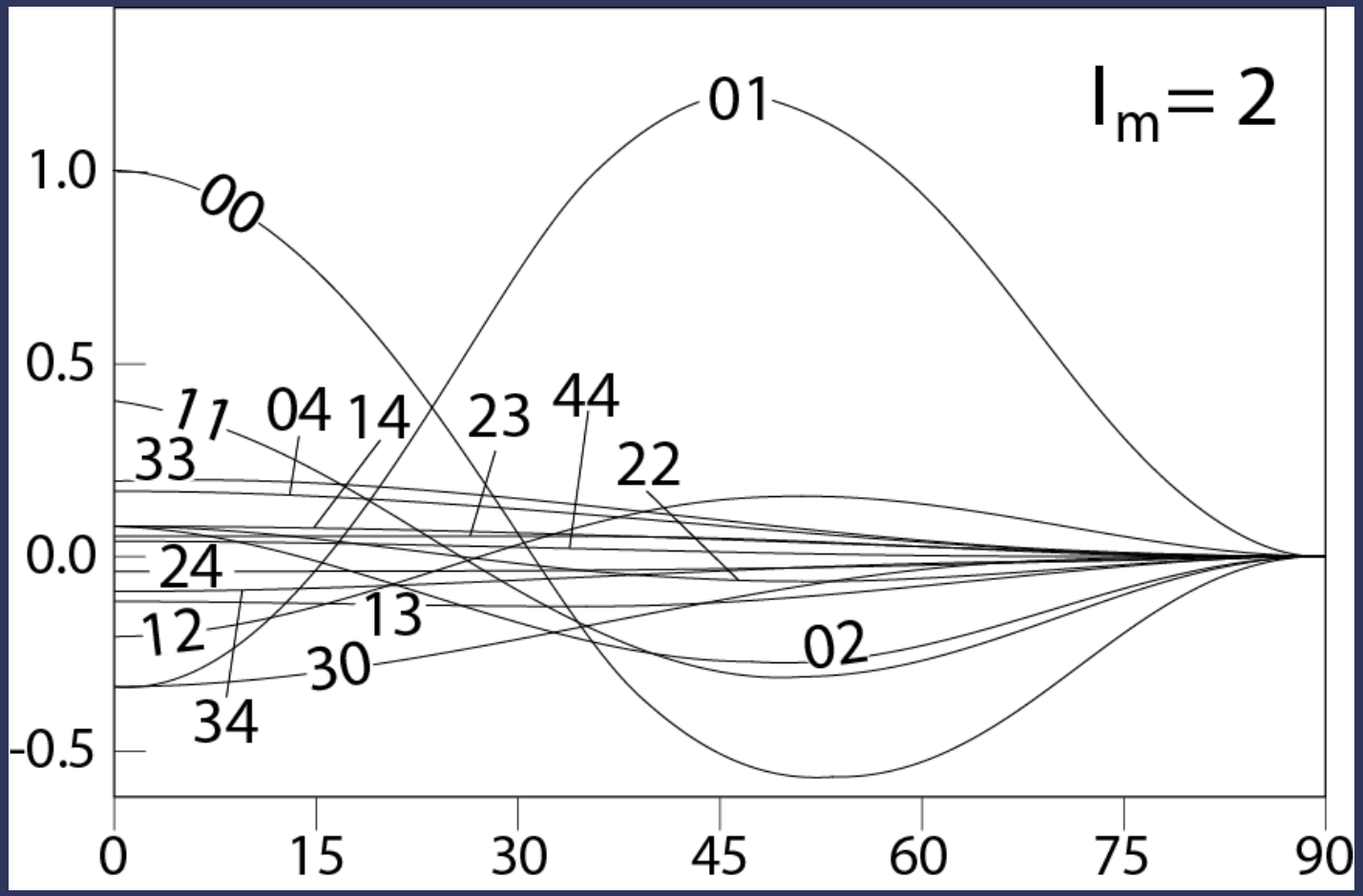
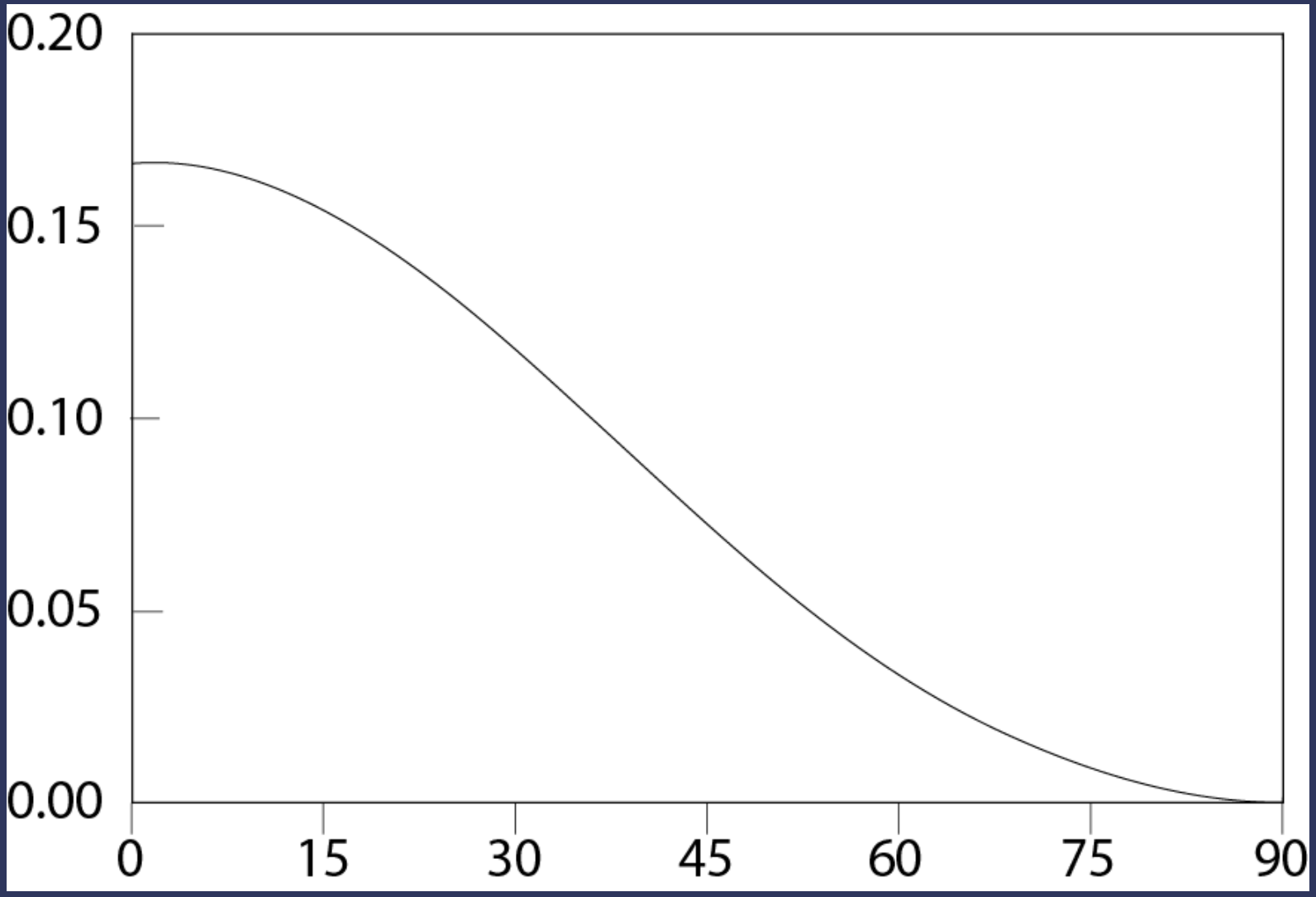
$l_m = 2$
$l_m = 3$
$l_m = 4$
$l_m = 5$
$l_m = 6$
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
0.3
0.2
0.1
0.0
-0.1
-0.2
0
15
30
45
60
75
90



FOI


$l_m = 2$
1.0
0.5
0.0
-0.5
0
15
30
45
60
75
90
00
01
11
04
14
23
44
33
22
24
13
12
30
02
34

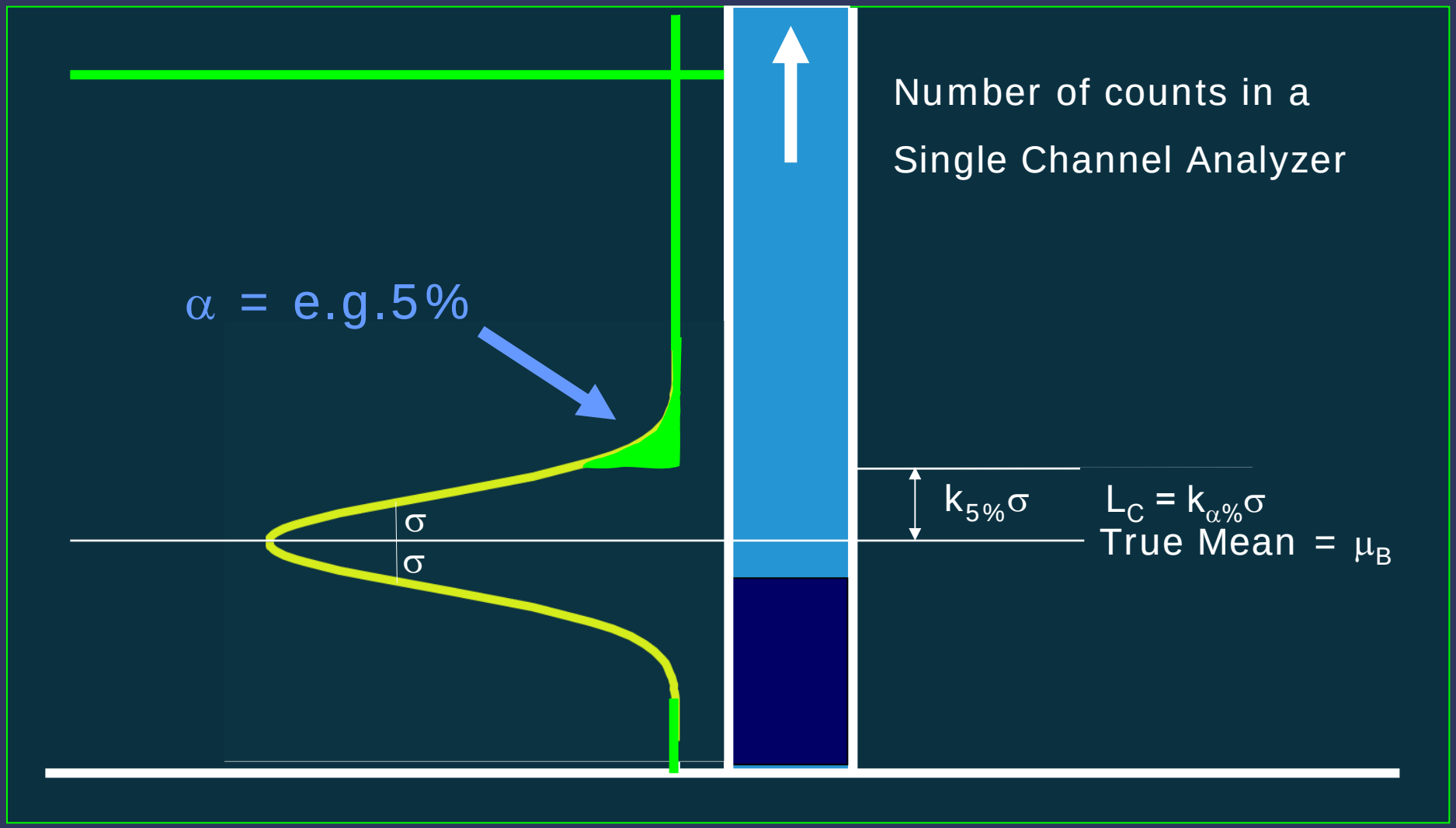


FOI

A Decent Currie

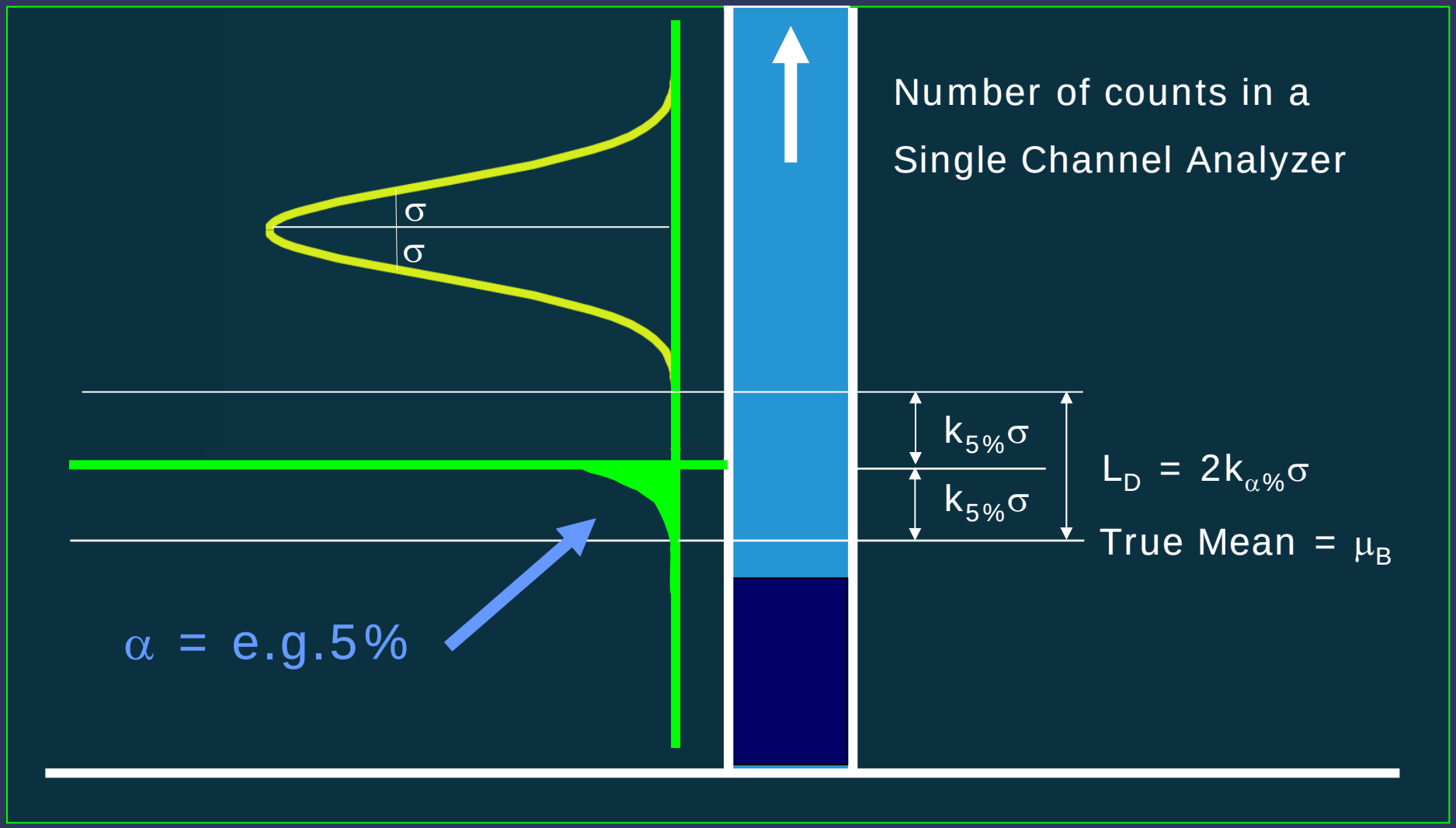
FOI

Applying the Currie SCA to gamma spectra



FOI

Applying the Currie SCA to gamma spectra



FOI

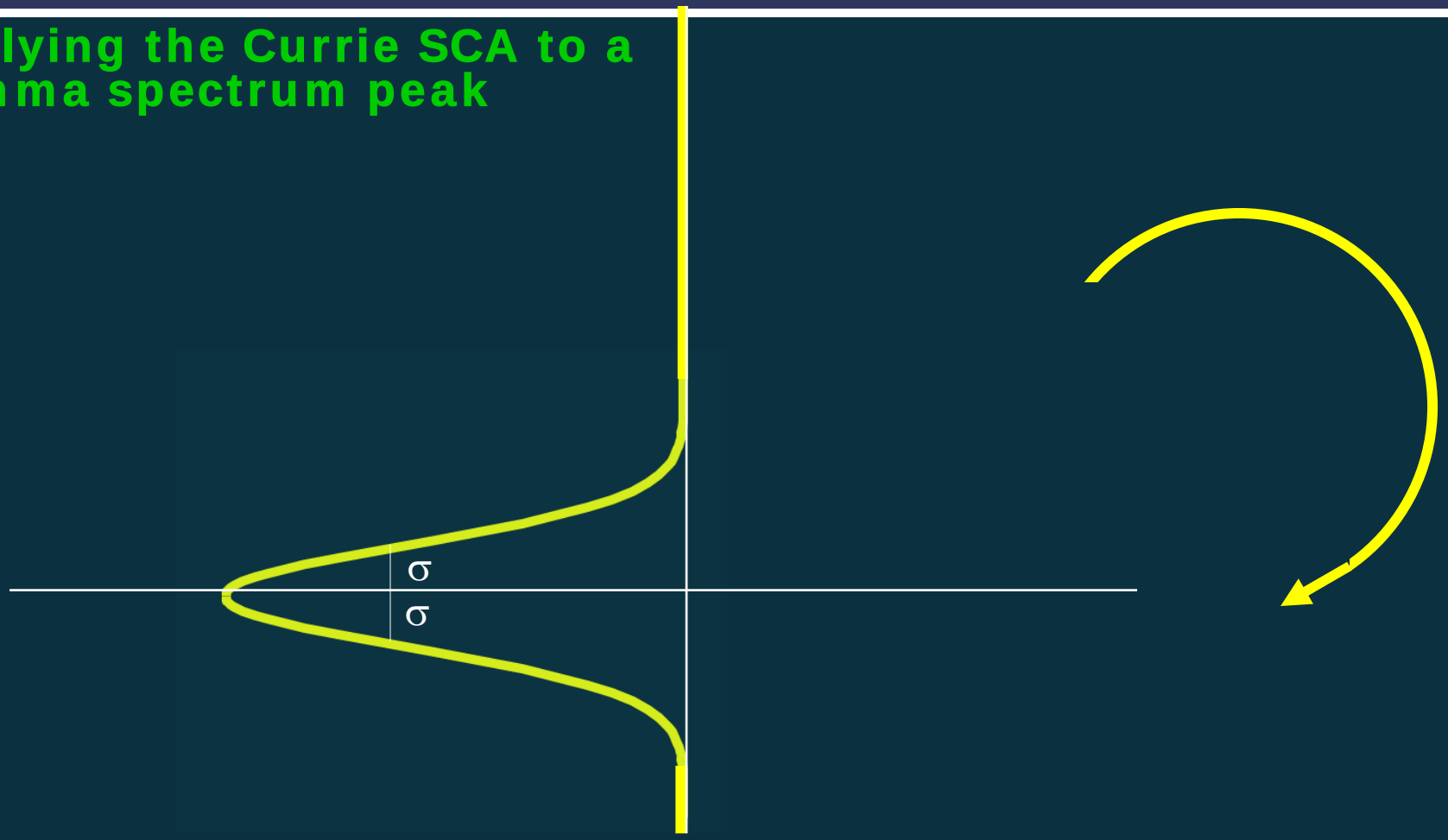
Lloyd Currie's classical paper from 1968

$$L_C = k\sqrt{\mu_B\,(1 + 1/m)}$$

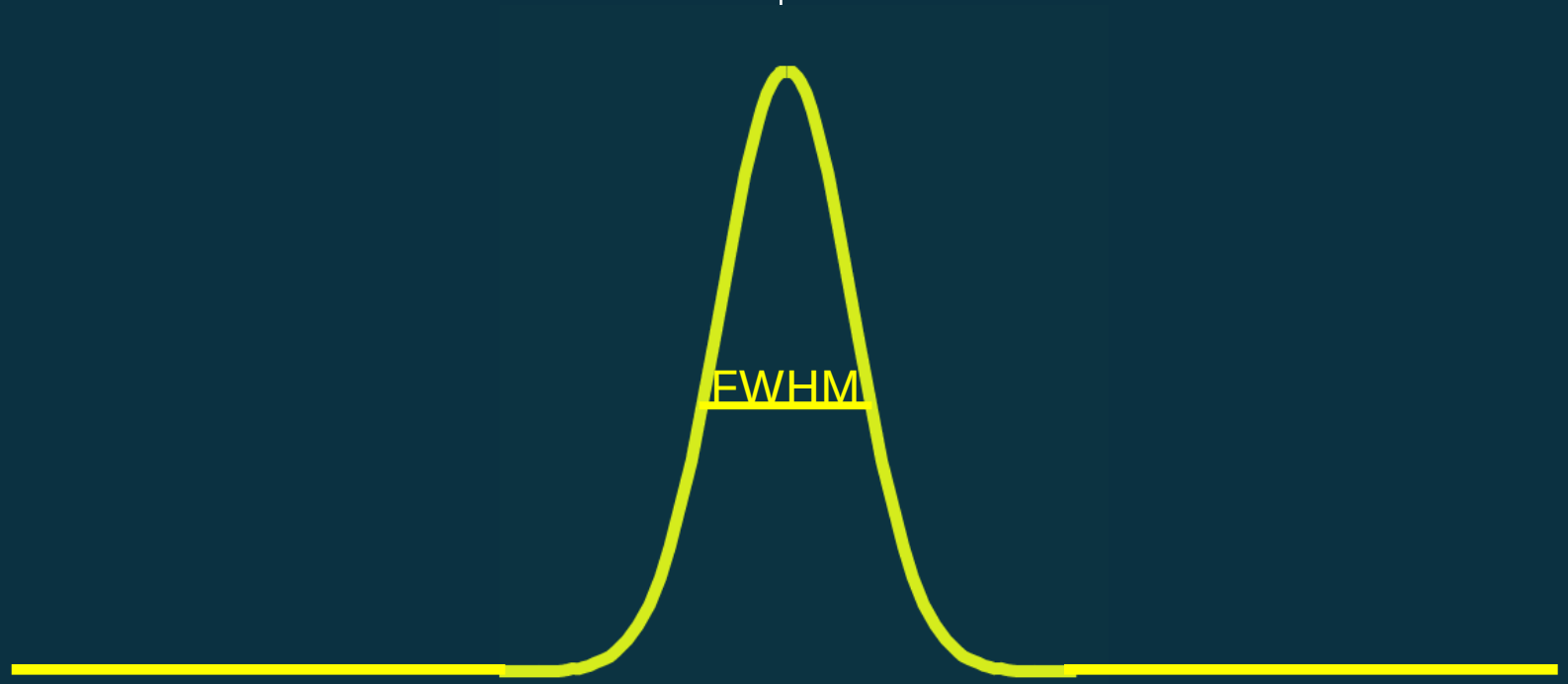
$$L_D = k^2 + 2L_C$$

FOI

Applying the Currie SCA to a gamma spectrum peak

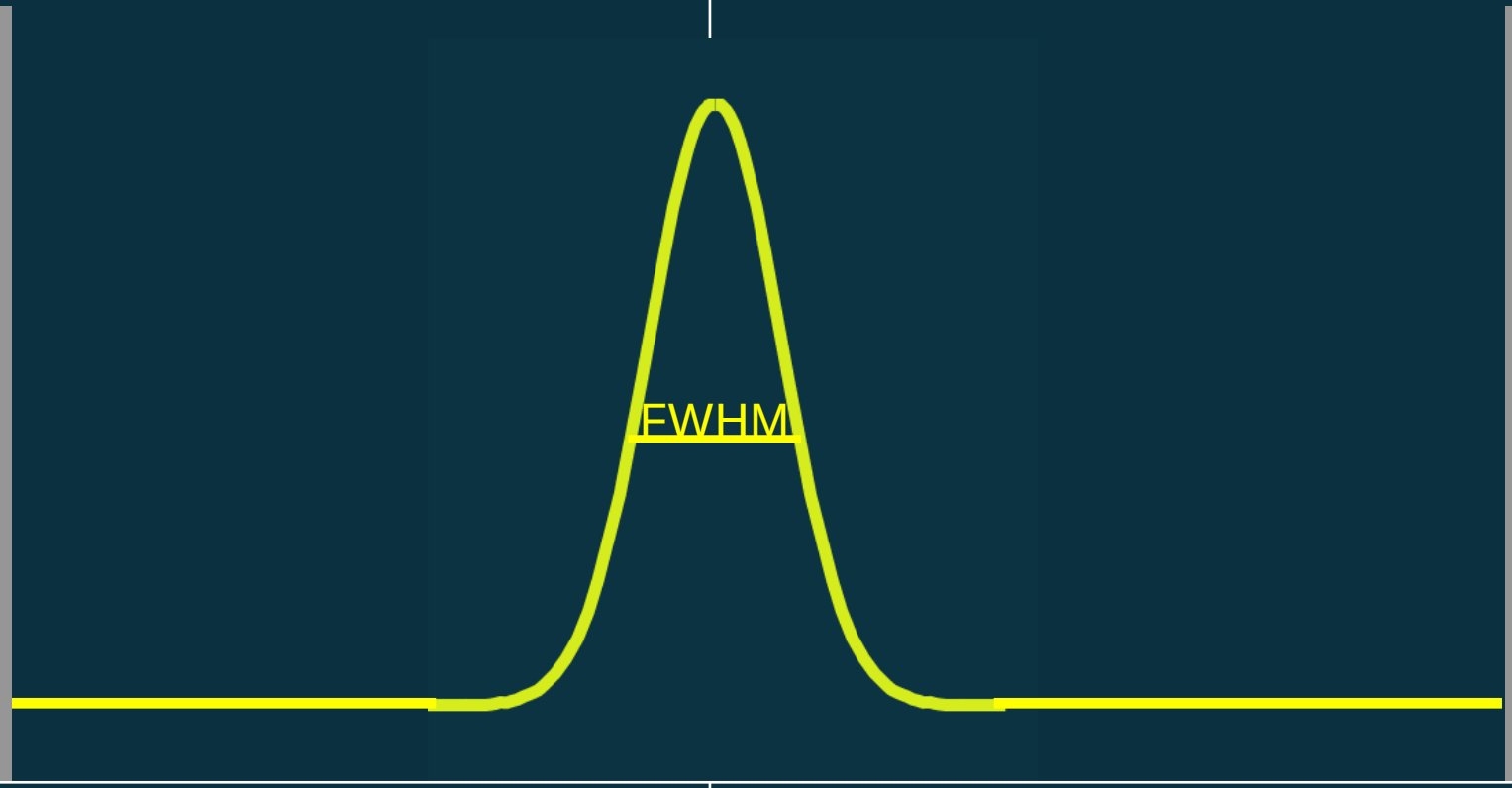


Applying the Currie SCA to a gamma spectrum peak



Applying the Currie SCA to a gamma spectrum peak

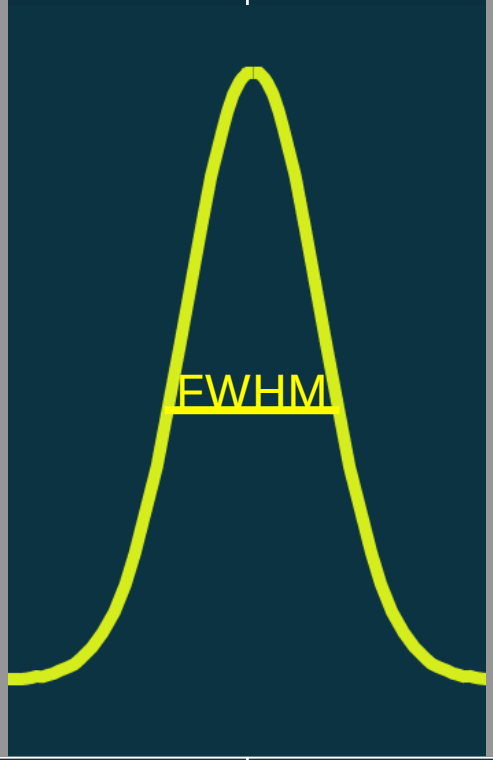
Applying the Currie SCA to a gamma spectrum peak



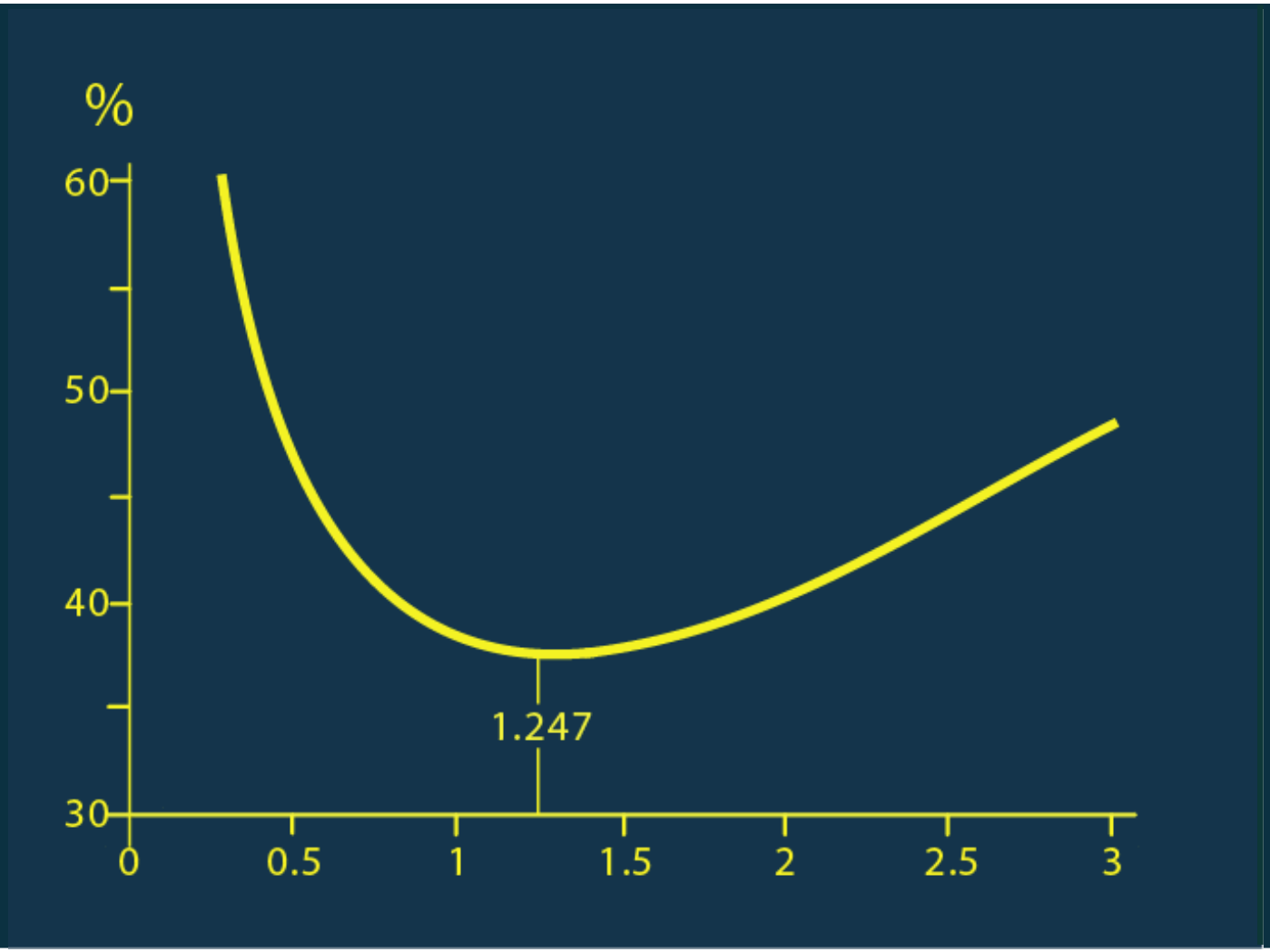
Applying the Currie SCA to a gamma spectrum peak

Commonly used width:

2.5 FWHM



FOI



Calculating the channel-width that gives the lowest relative uncertainty

$$L_C = k\sqrt{\mu_B\,(1 + 1/m)}$$

With the SCA-width (and thus μ_B) reduced by a factor of 2 and m conside-red large instead of 1,

L_C is reduced by a factor of 2.

This can be compensated by doubling k, which is equivalent to reducing α, the risks for errors of the first and second kind, from e.g. 5% to 0.05%.

Still $L_D = 2L_C$

This is much more consistent with experience, as we normally see just around five false positives in a 8192 channel spectrum and not hundreds of them which we would if the risk was really 5%.

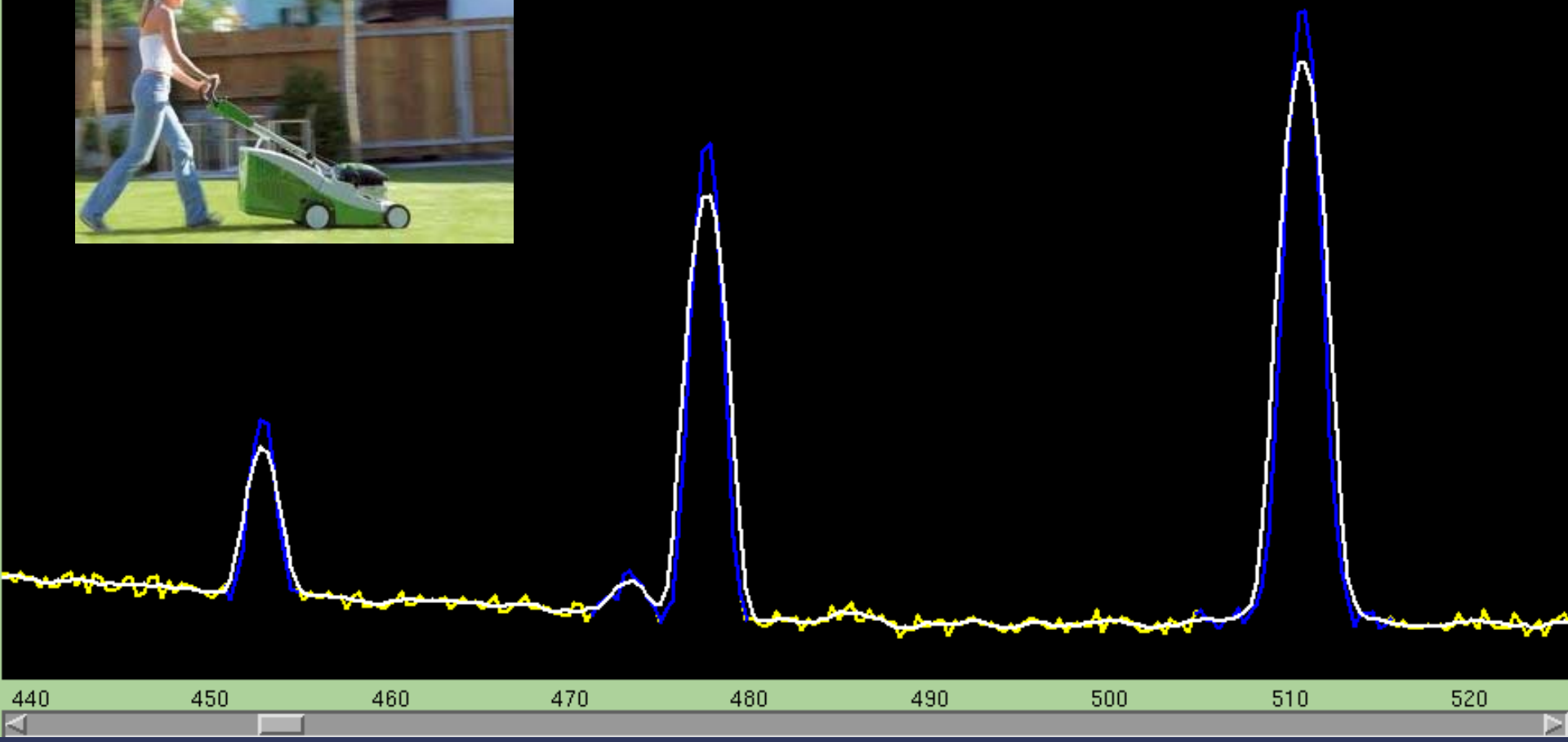
FOI

So how do we now utilize this in a spectrum where we a priori don't know where all peaks are?

1. Pick all clear and nice peaks away from the spectrum.
2. We need a good background line and we can now get one by smoothing the picked spectrum.
3. Assume all channels are the centroid of a small peak.
4. Add the channels within 1.25 FWHM of each channel in the spectrum and write the sum into the centroid channel. This involves also partial channels at each end of the SCA.
5. Compare with the L_C criterion. If channel content is > L_C it's part of a peak, otherwise not.

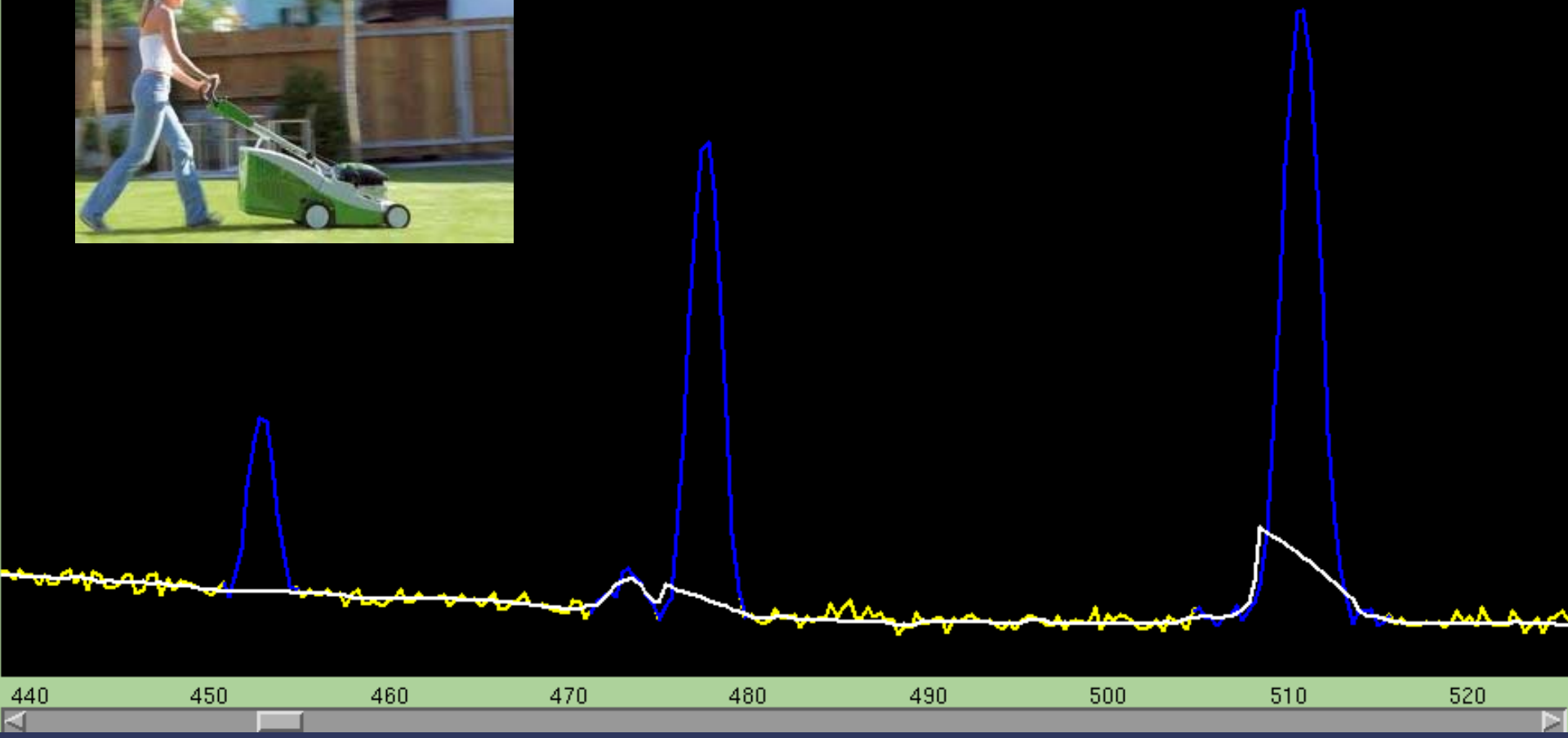
FOI

Lawnmower operation



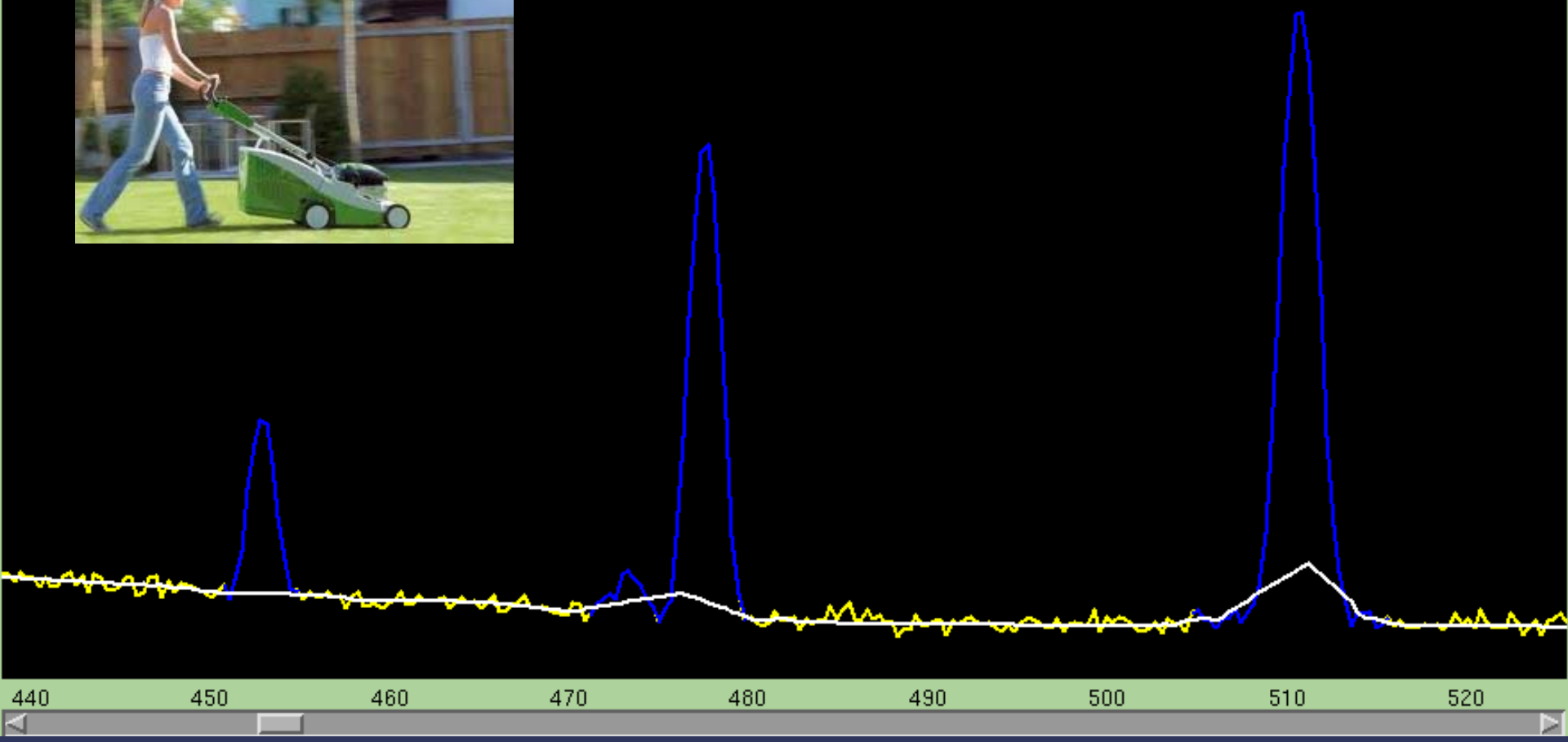
FOI

Lawnmower operation



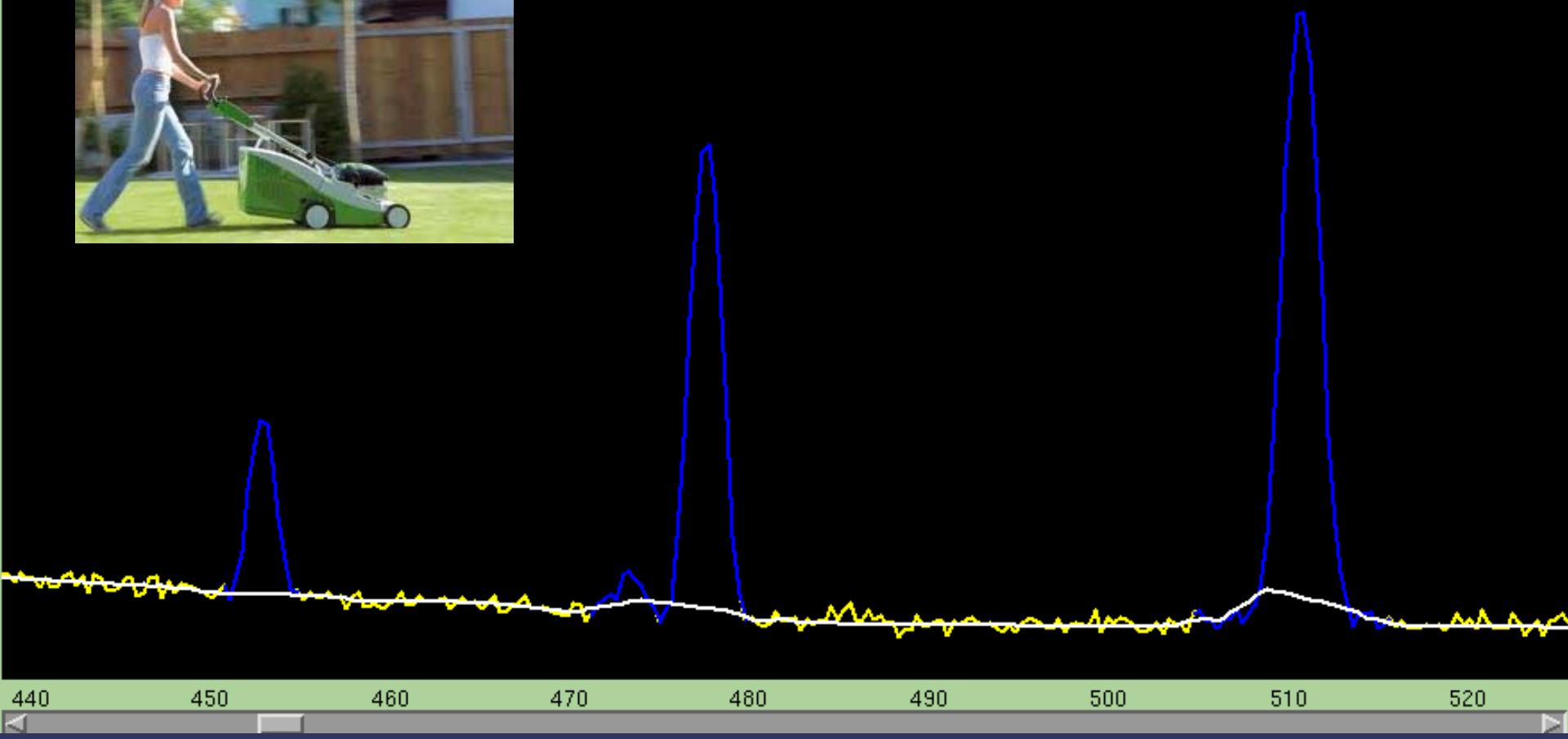
FOI

Lawnmower operation



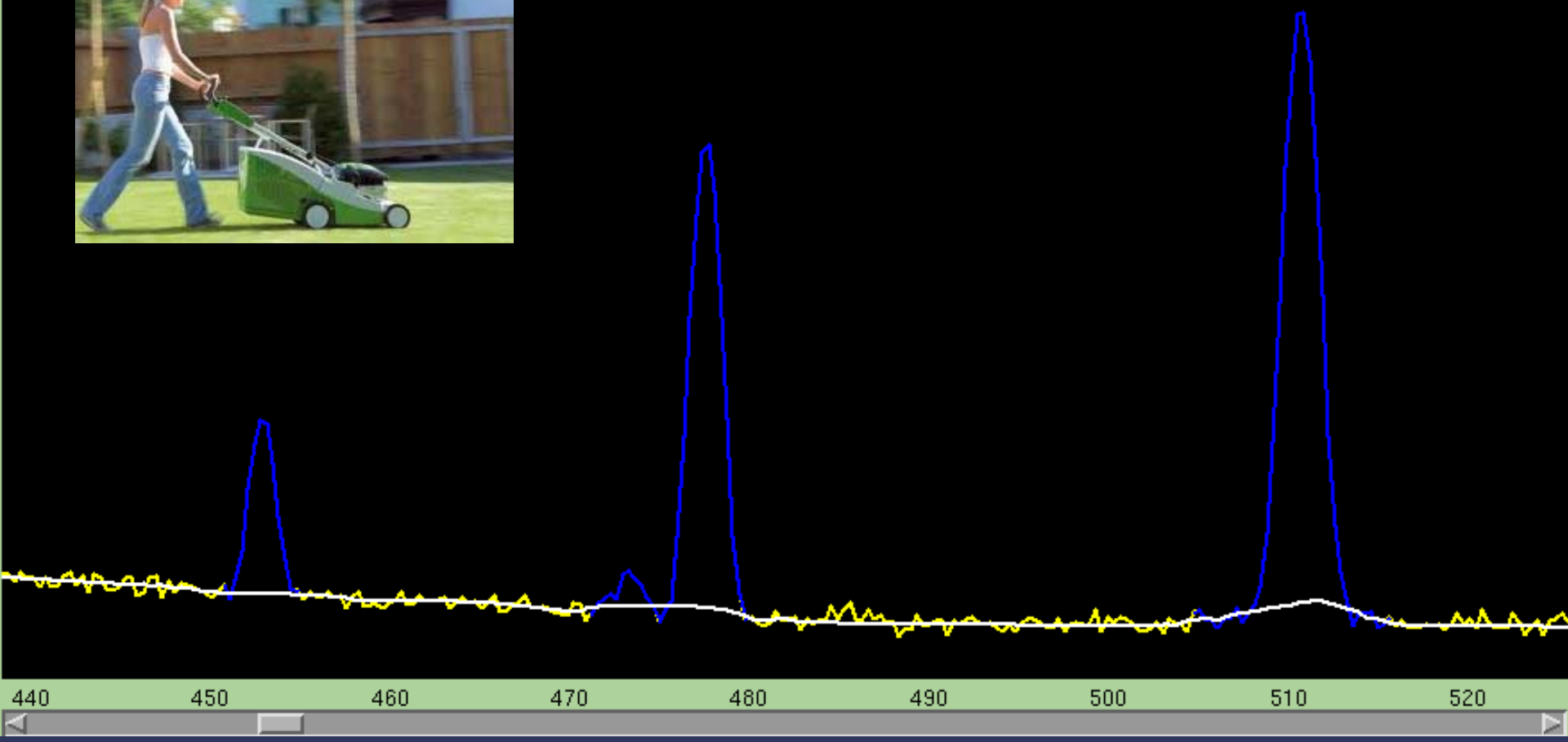
FOI

Lawnmower operation



FOI

Lawnmower operation



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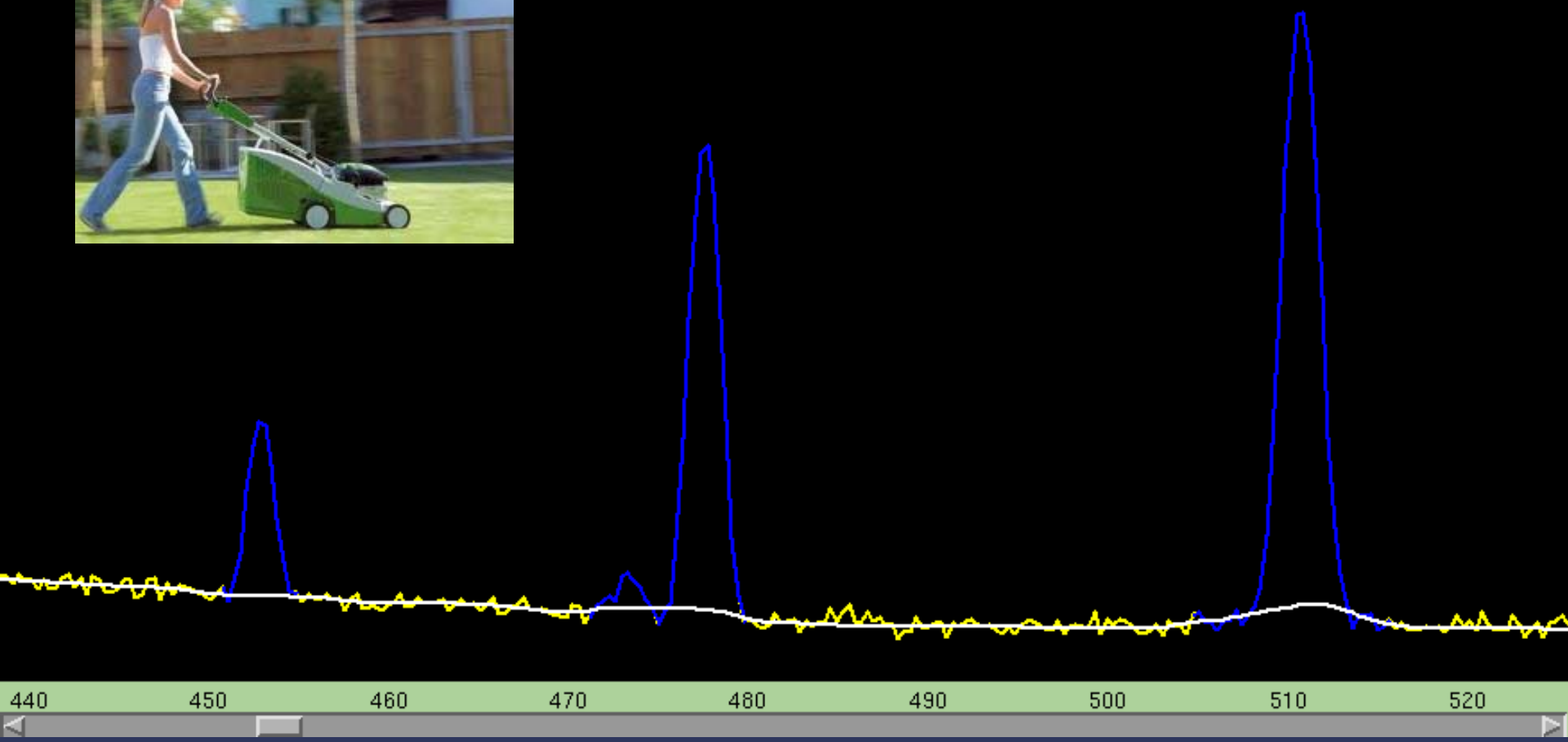
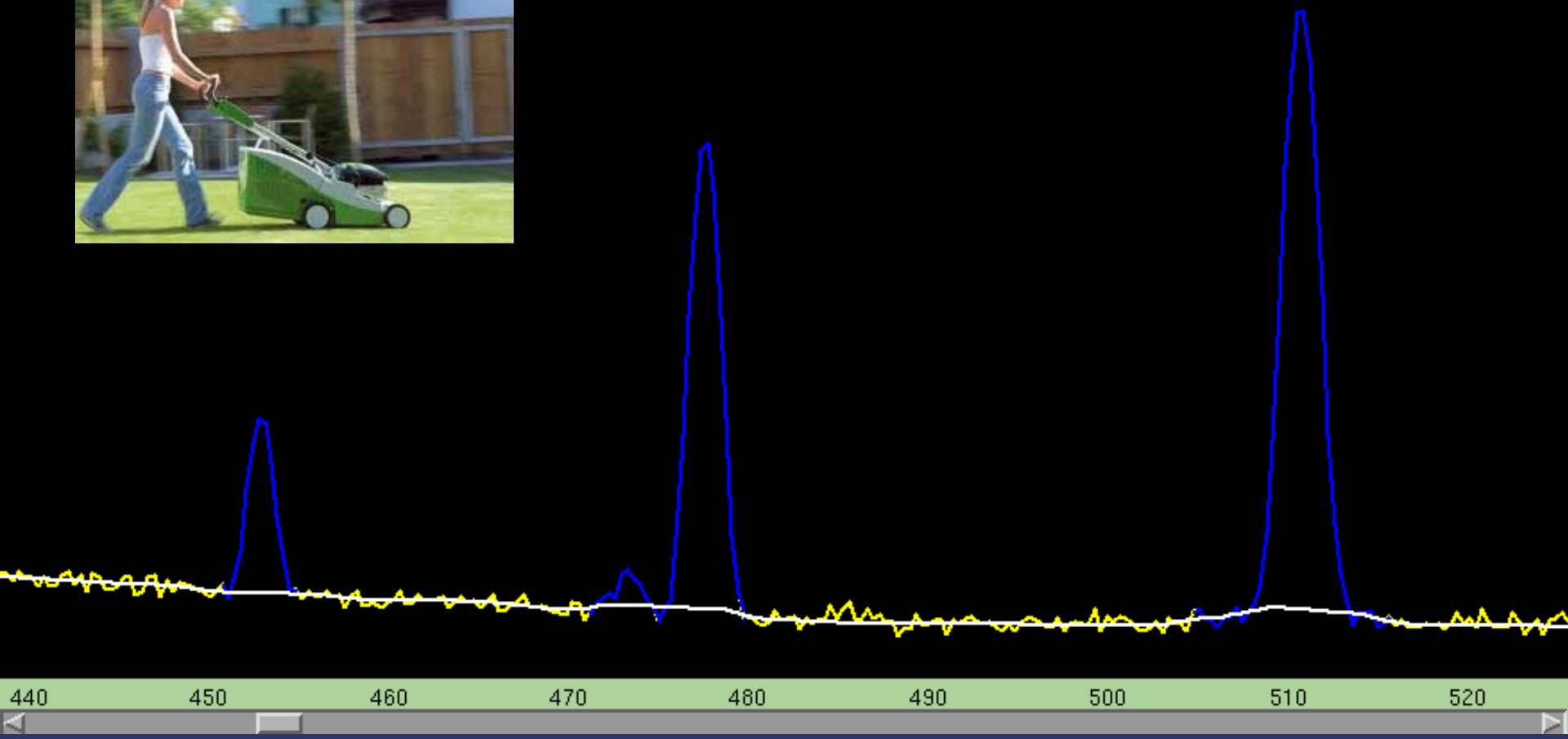
Lawnmower operation



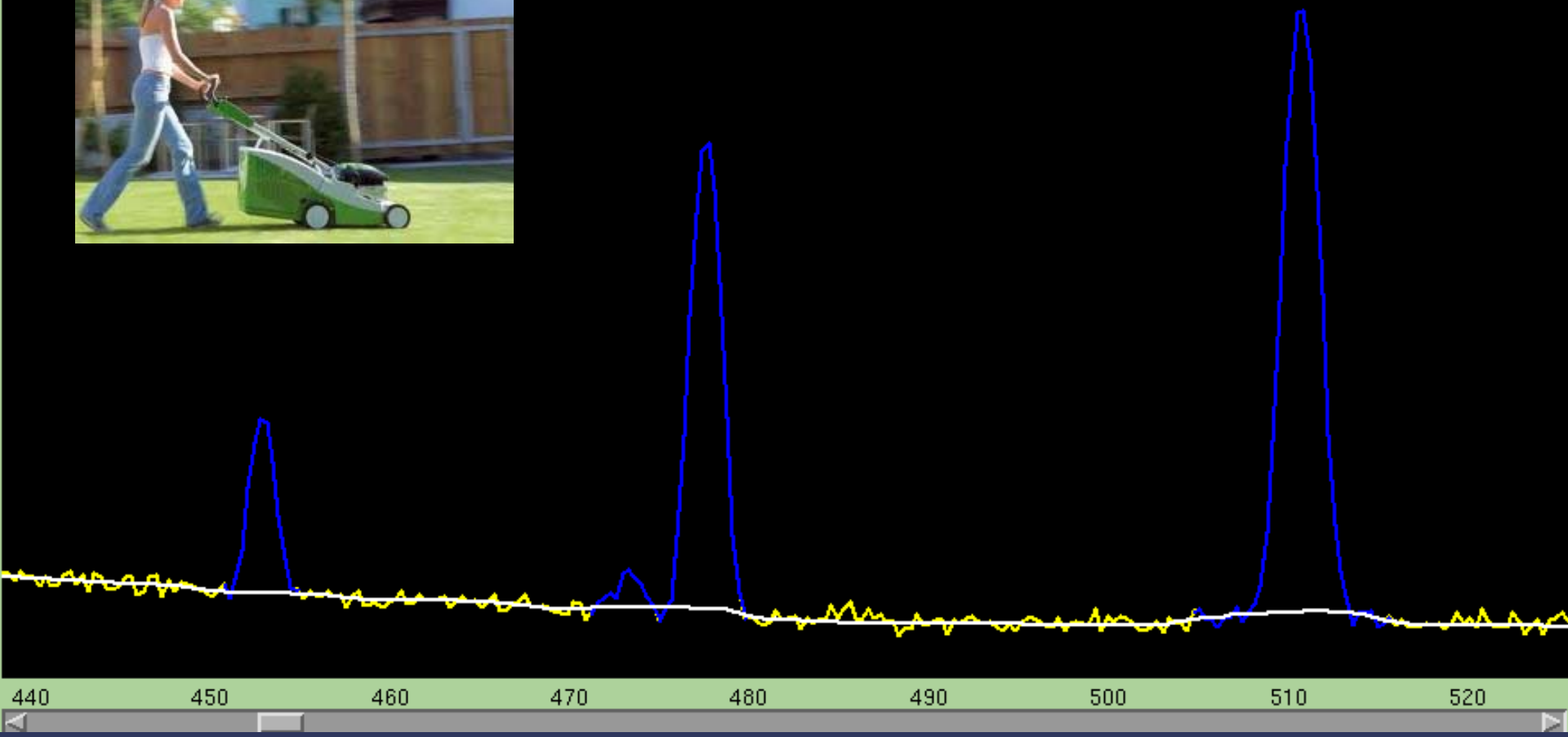
FOI

Lawnmower operation



FOI

Lawnmower operation



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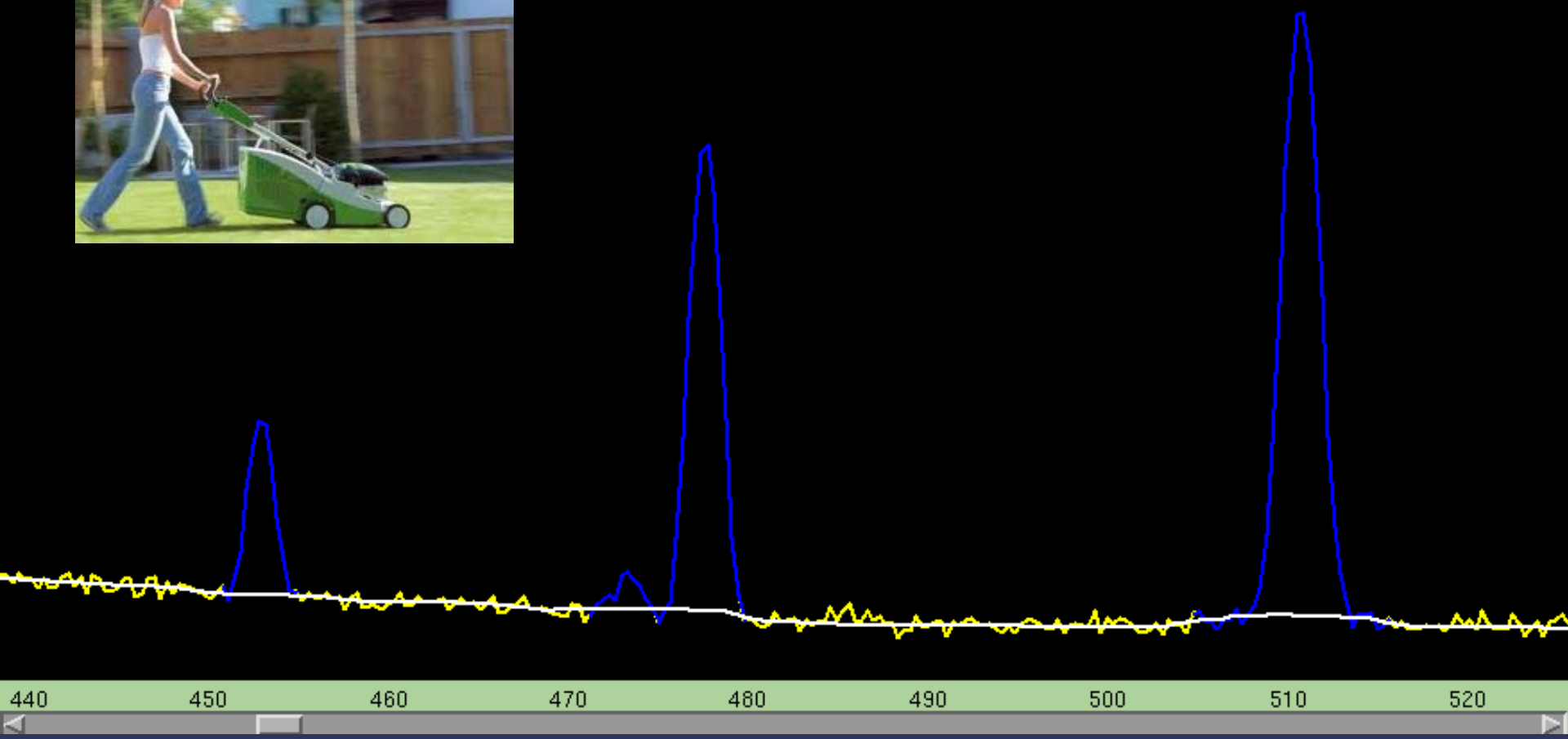
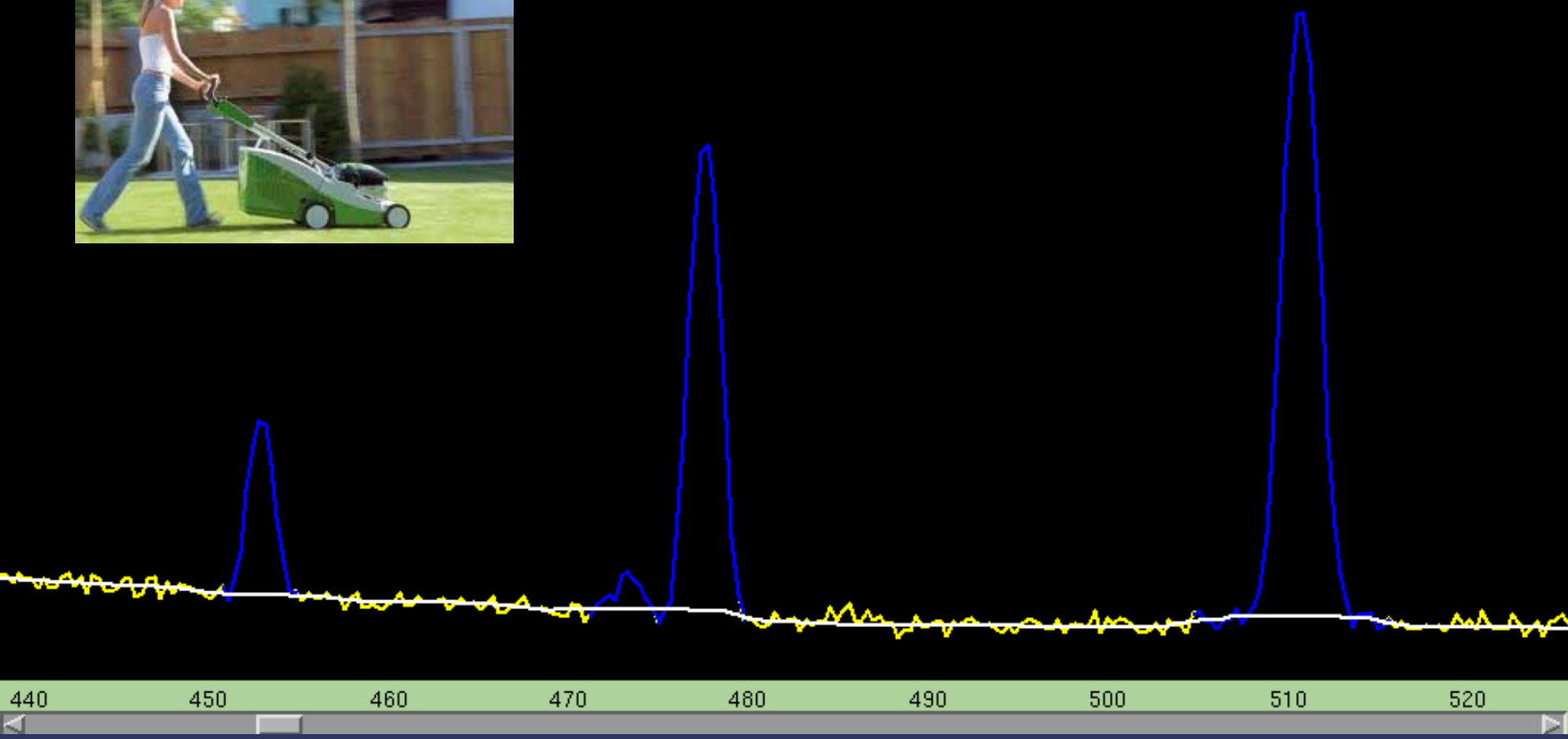
Lawnmower operation



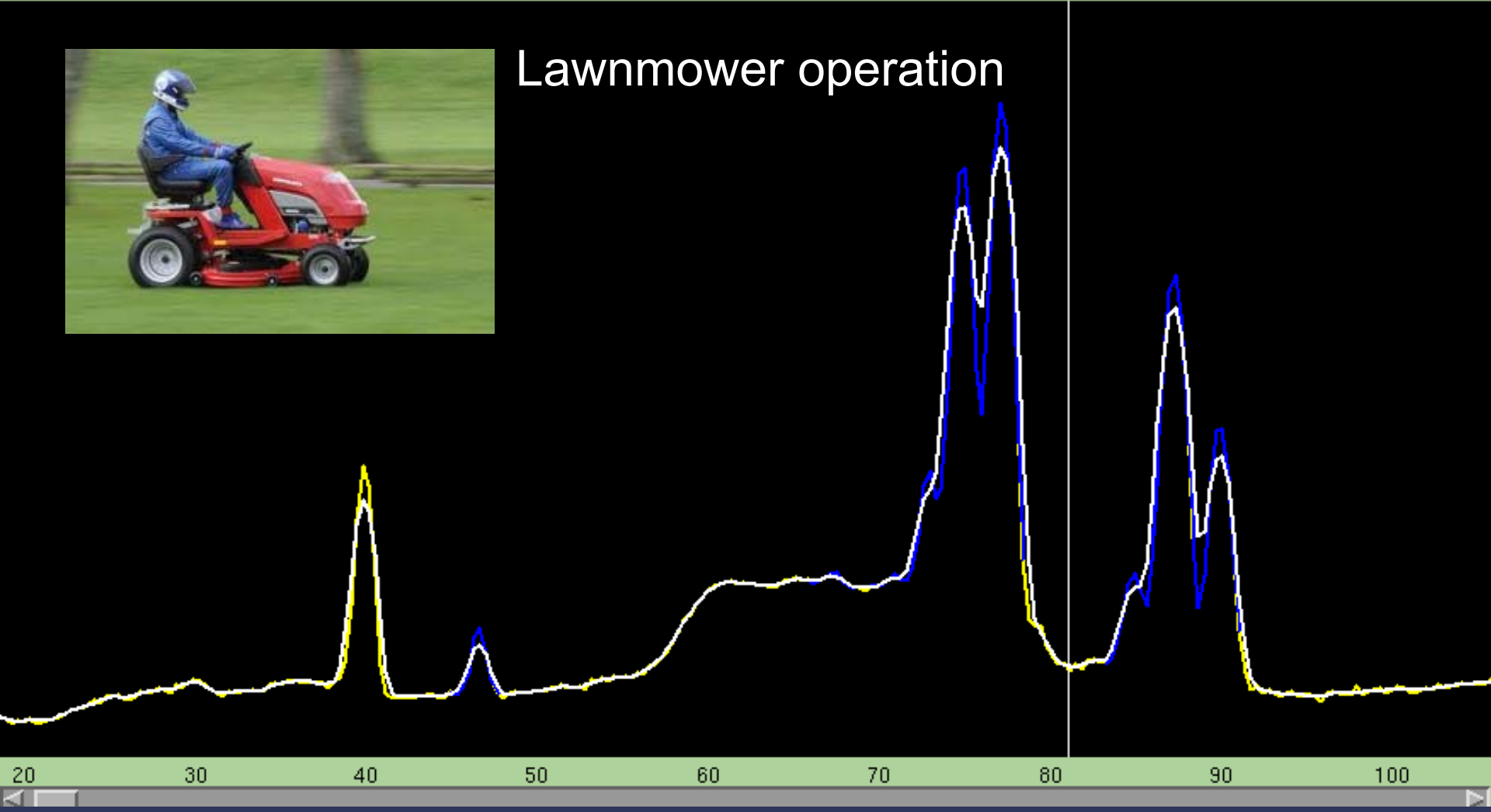
FOI

Lawnmower operation



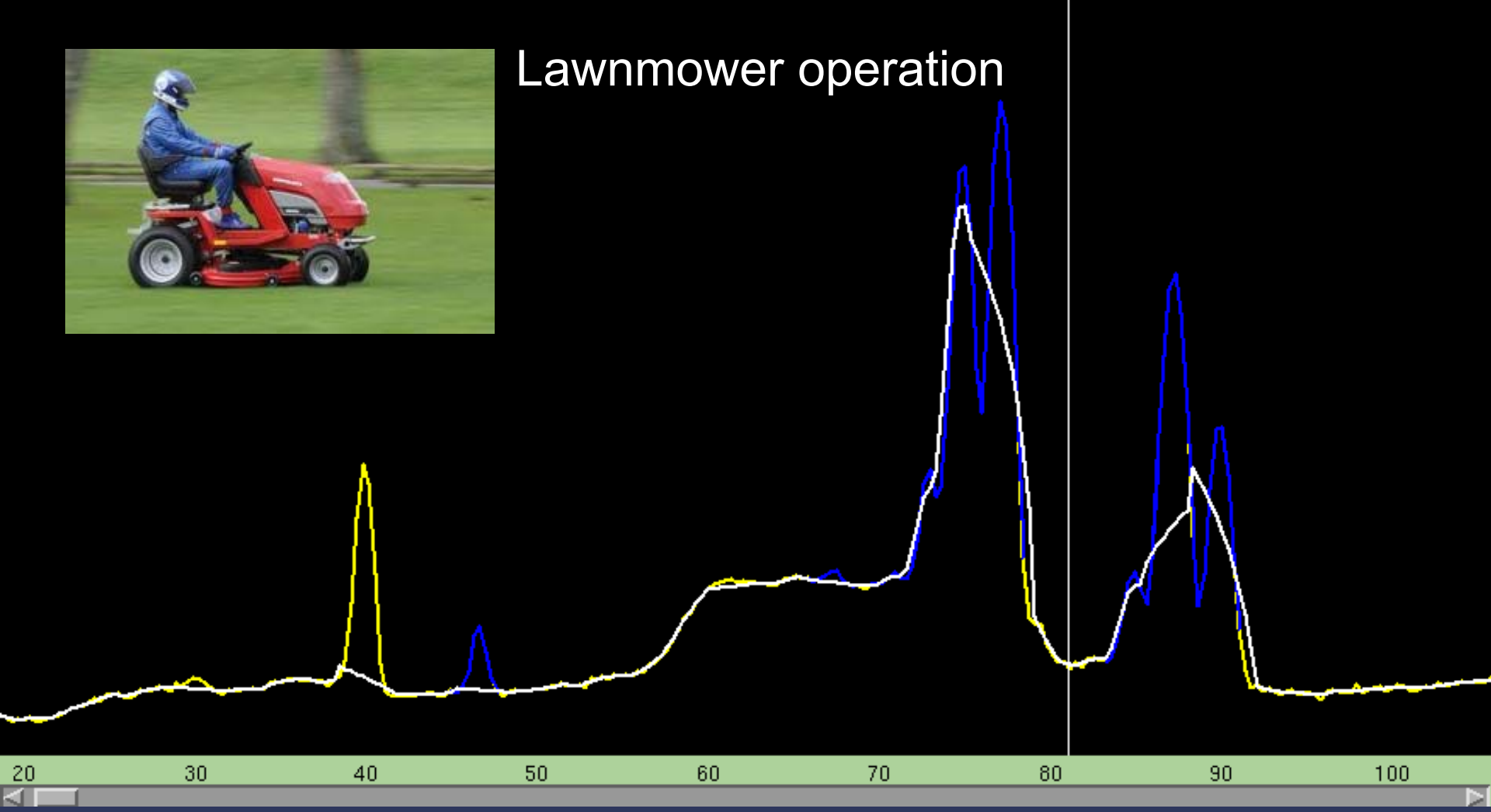
FOI

Lawnmower operation



FOI

Lawnmower operation



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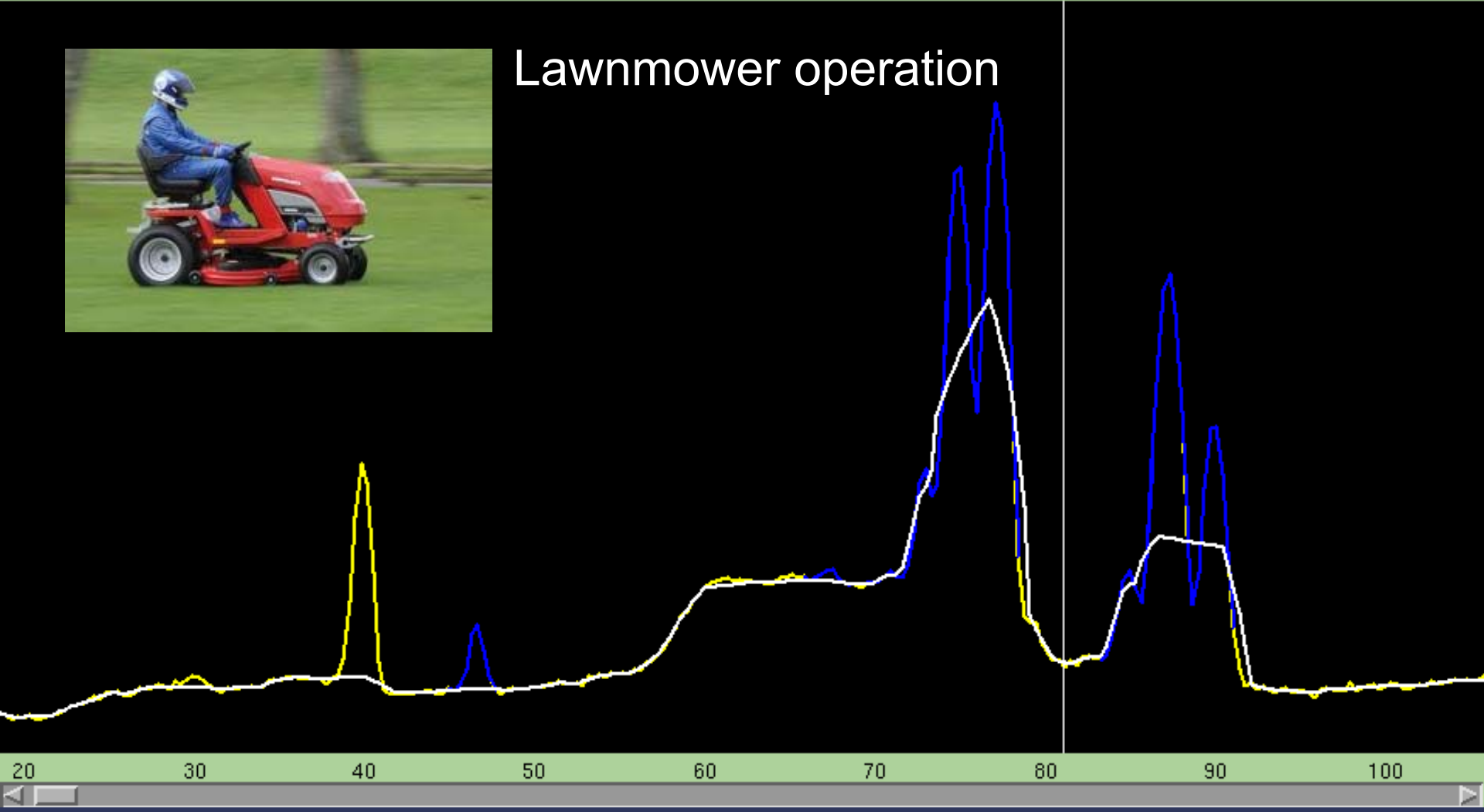
Lawnmower operation



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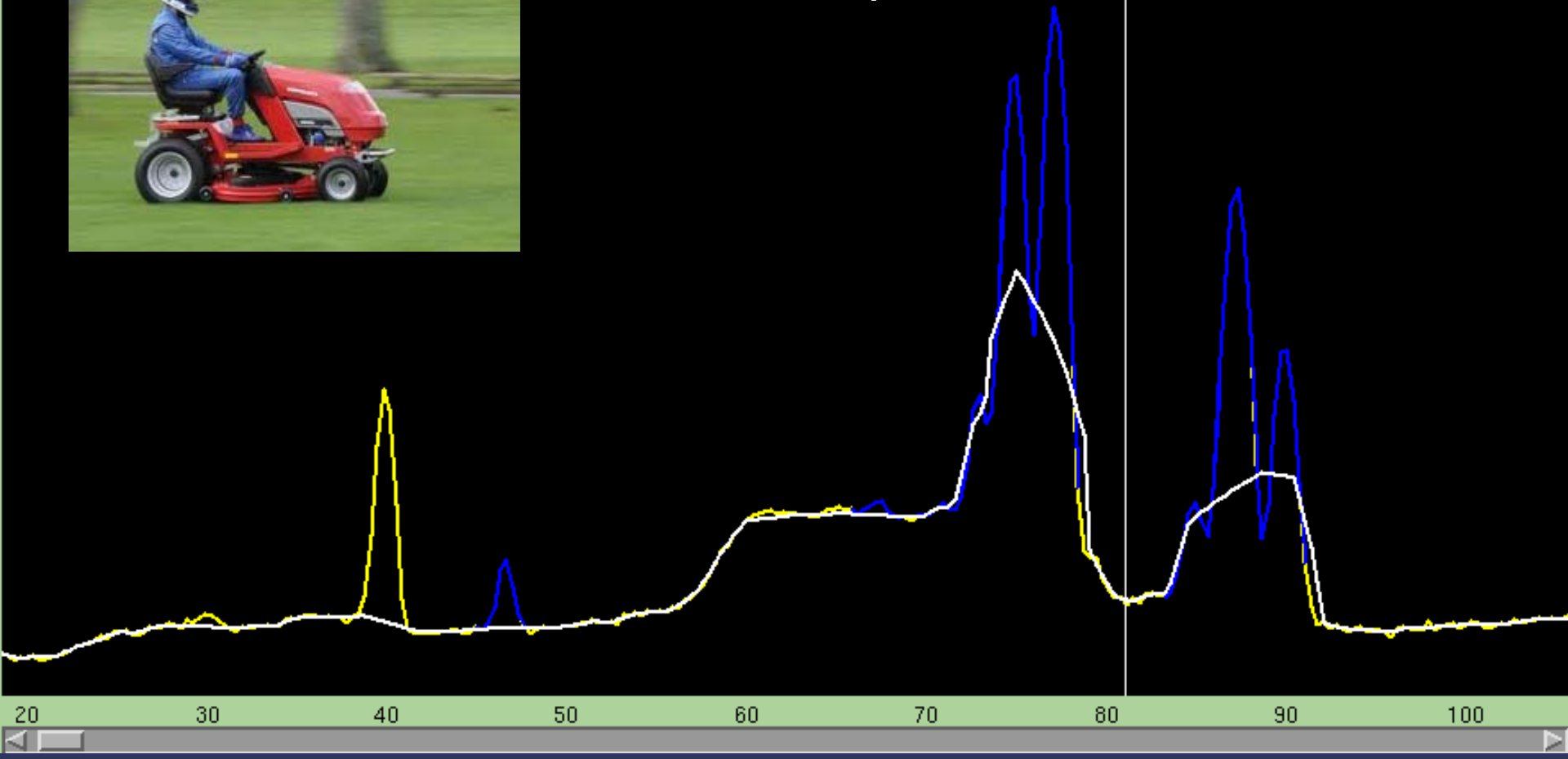
Lawnmower operation



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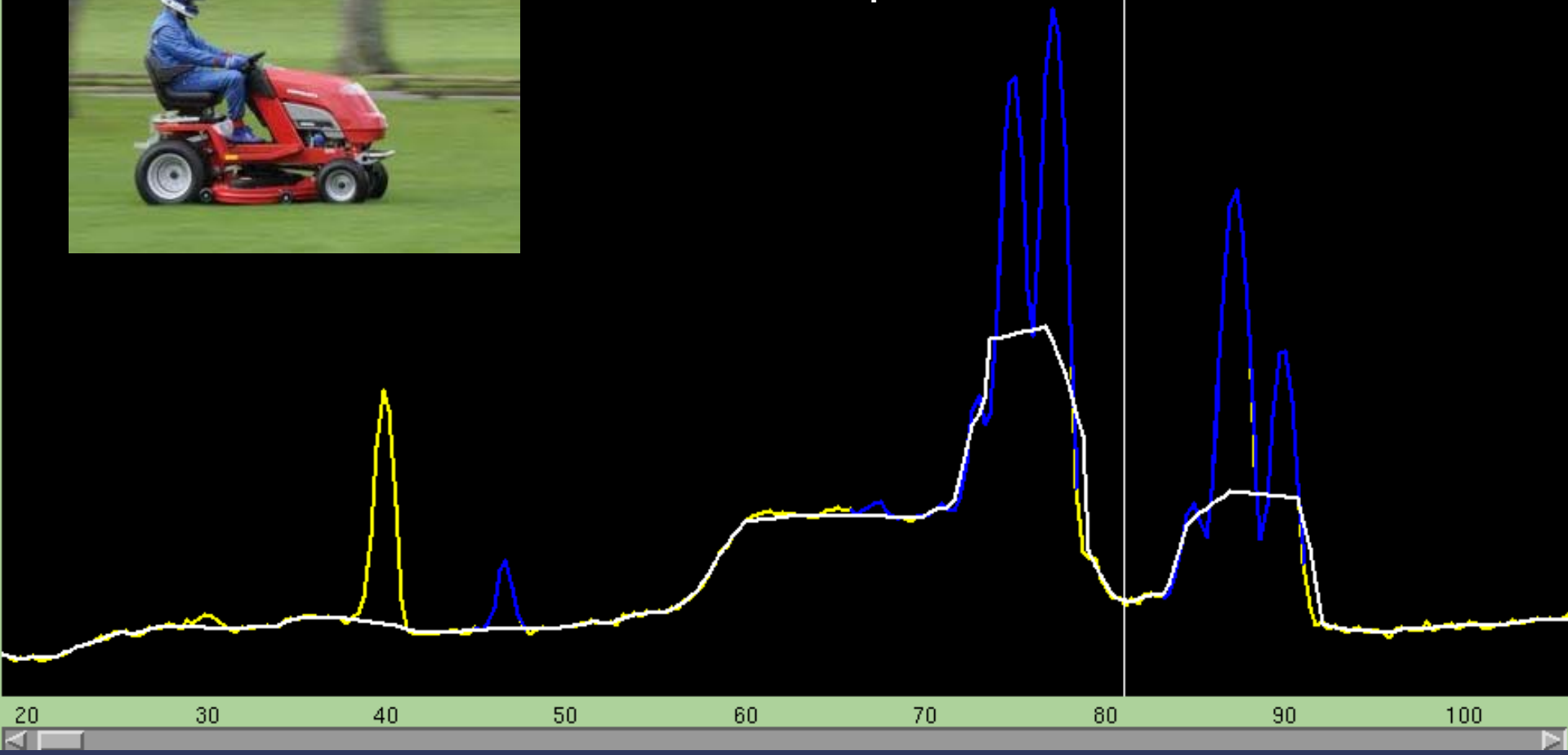
Lawnmower operation



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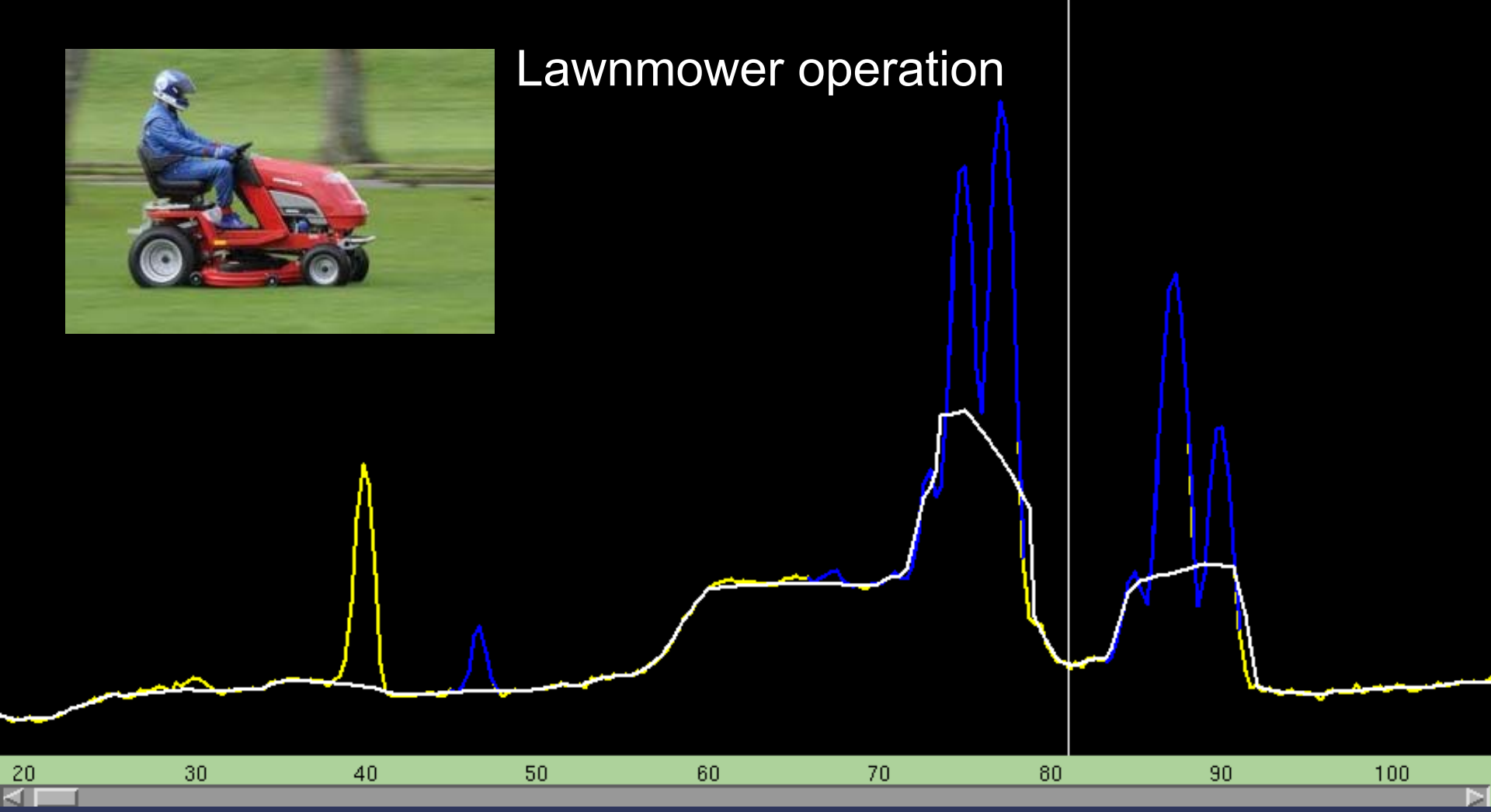
Lawnmower operation



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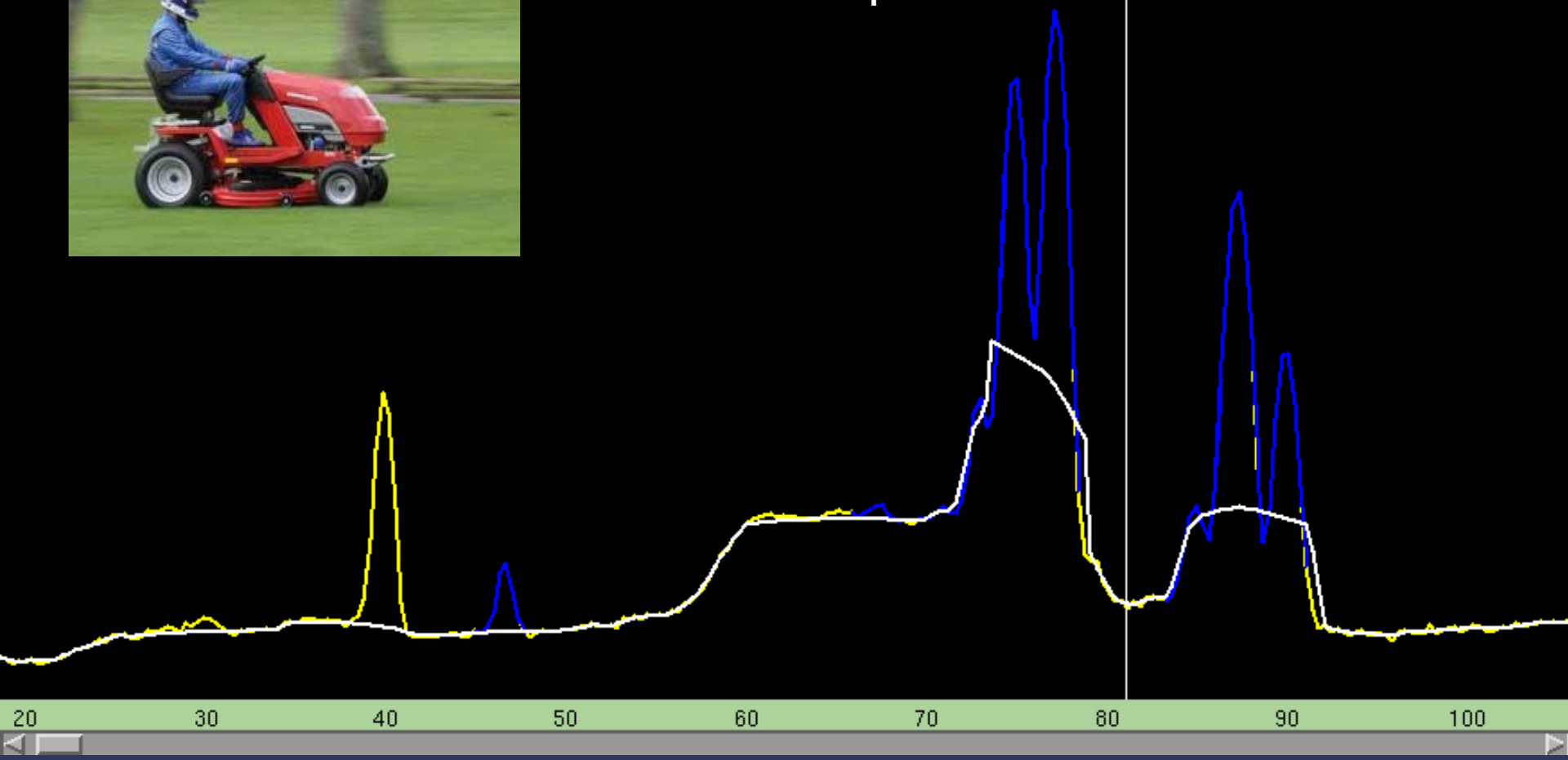
Lawnmower operation



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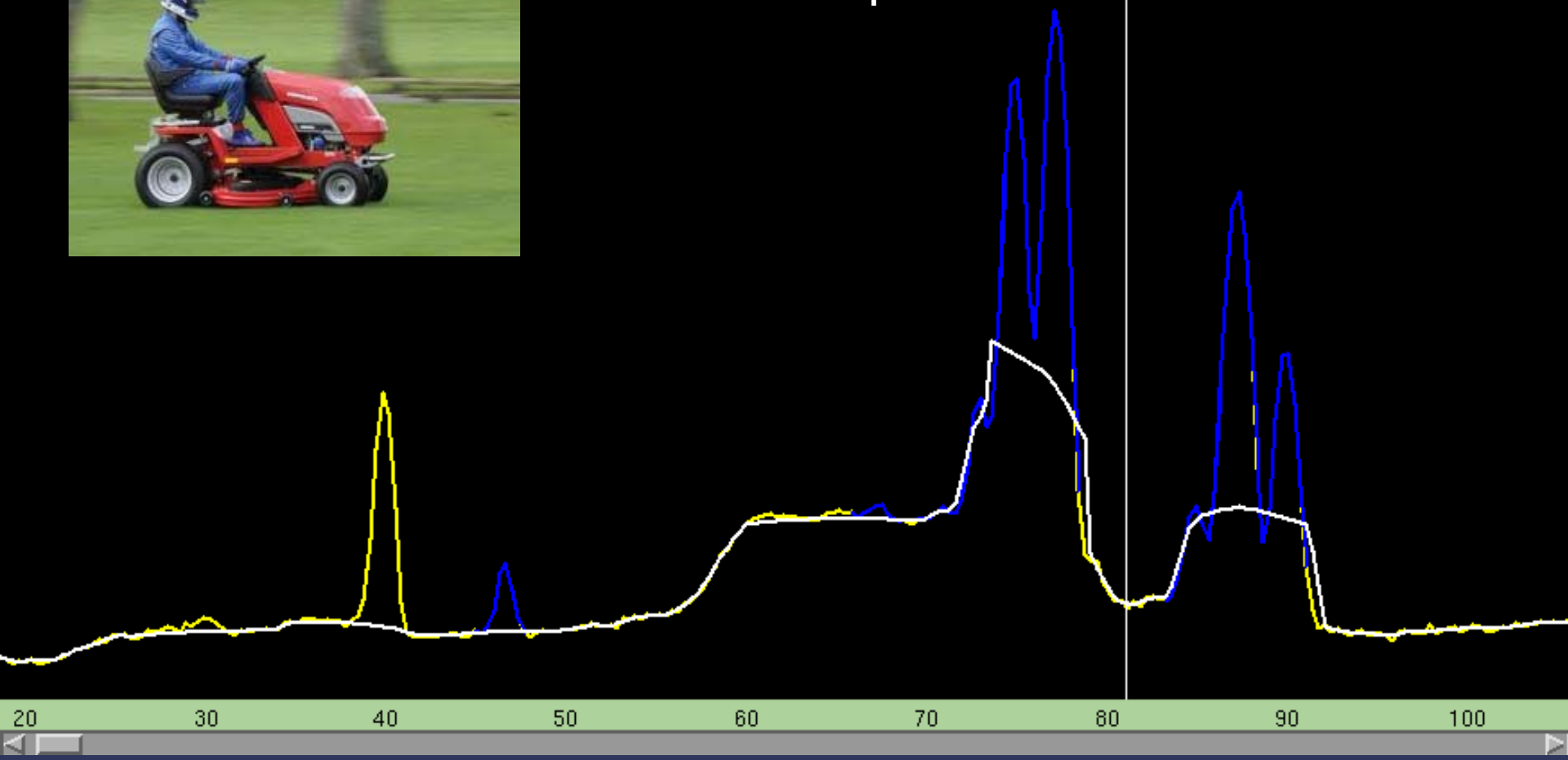
Lawnmower operation



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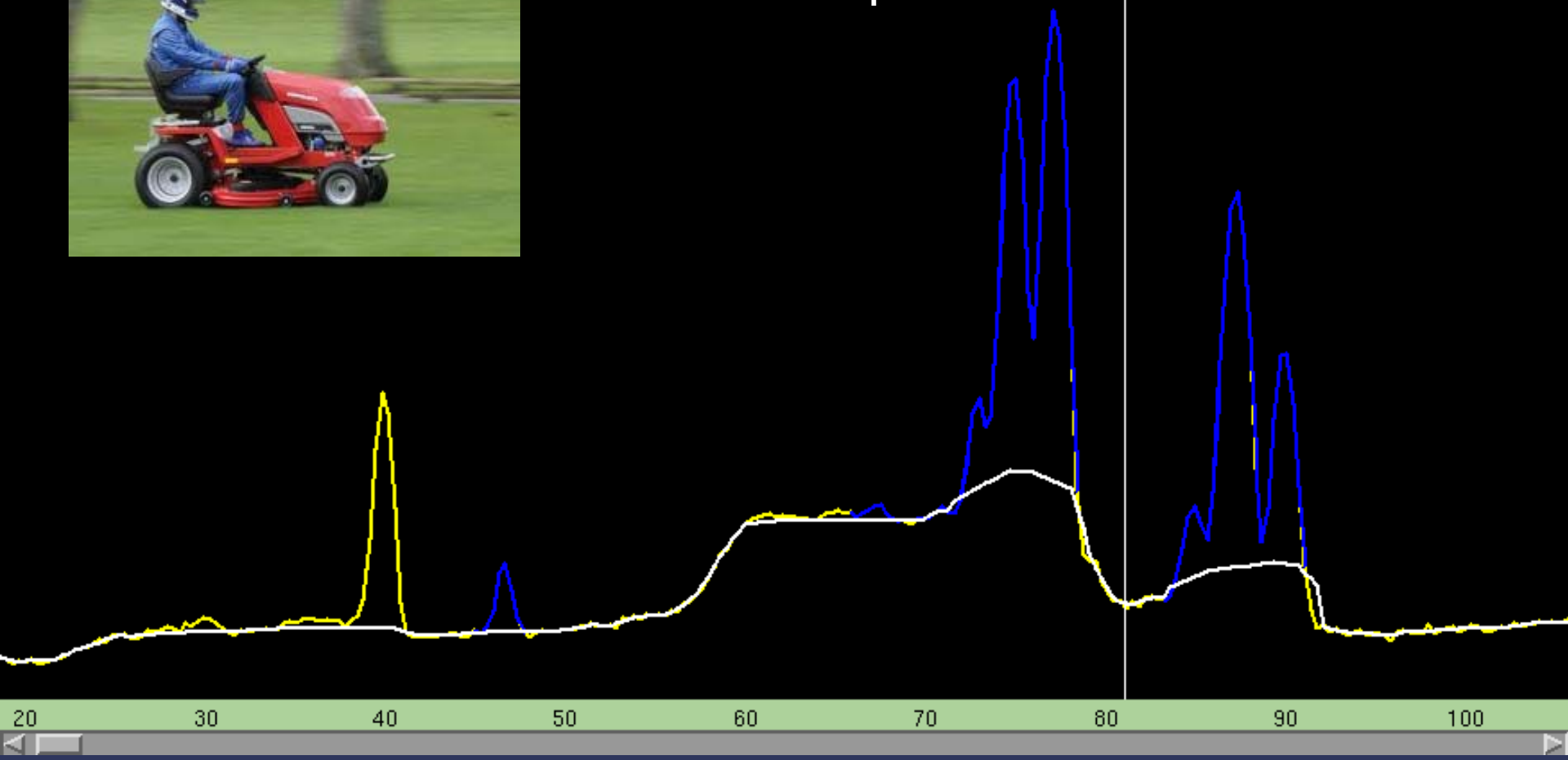
Lawnmower operation



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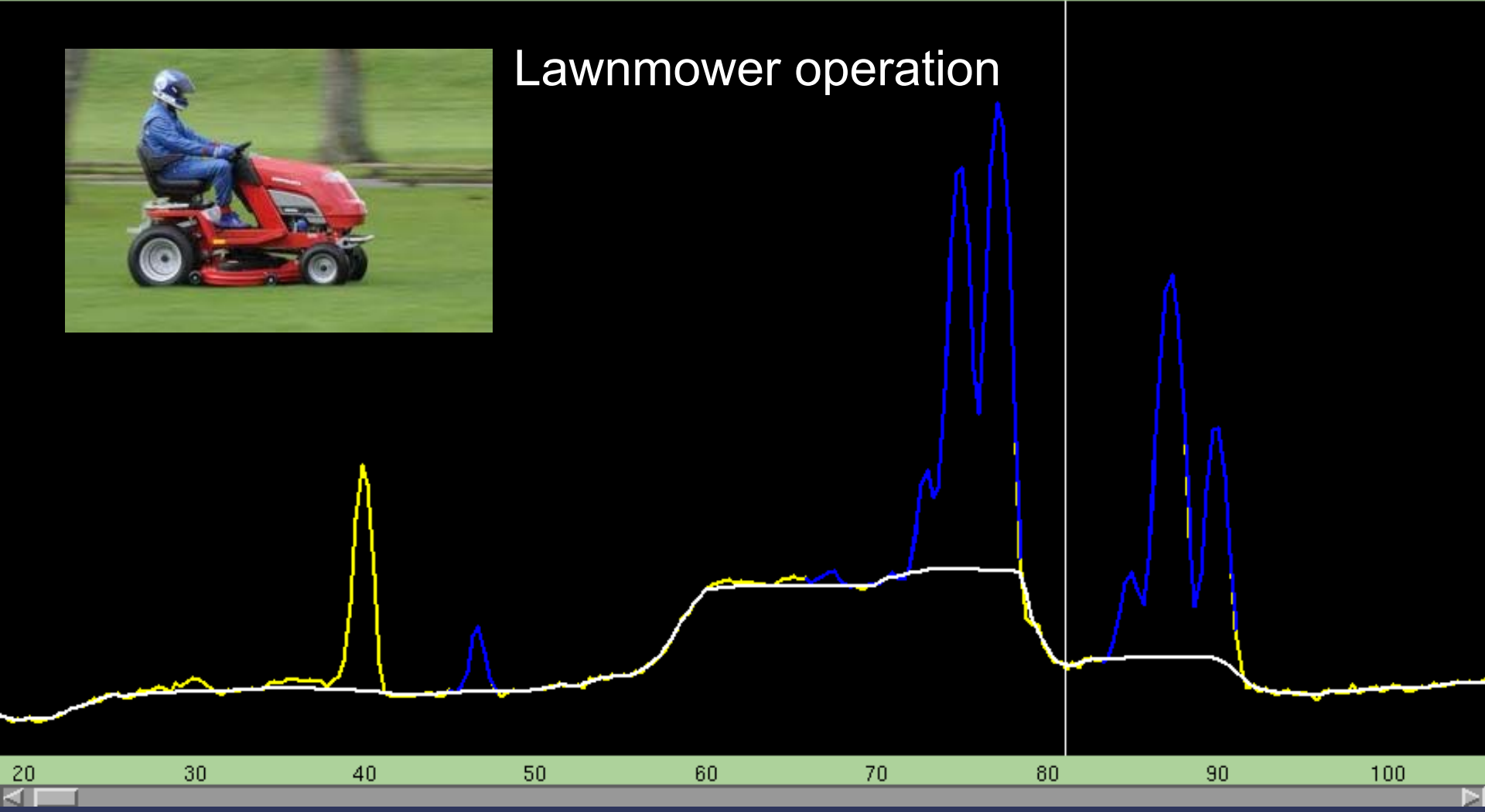
Lawnmower operation



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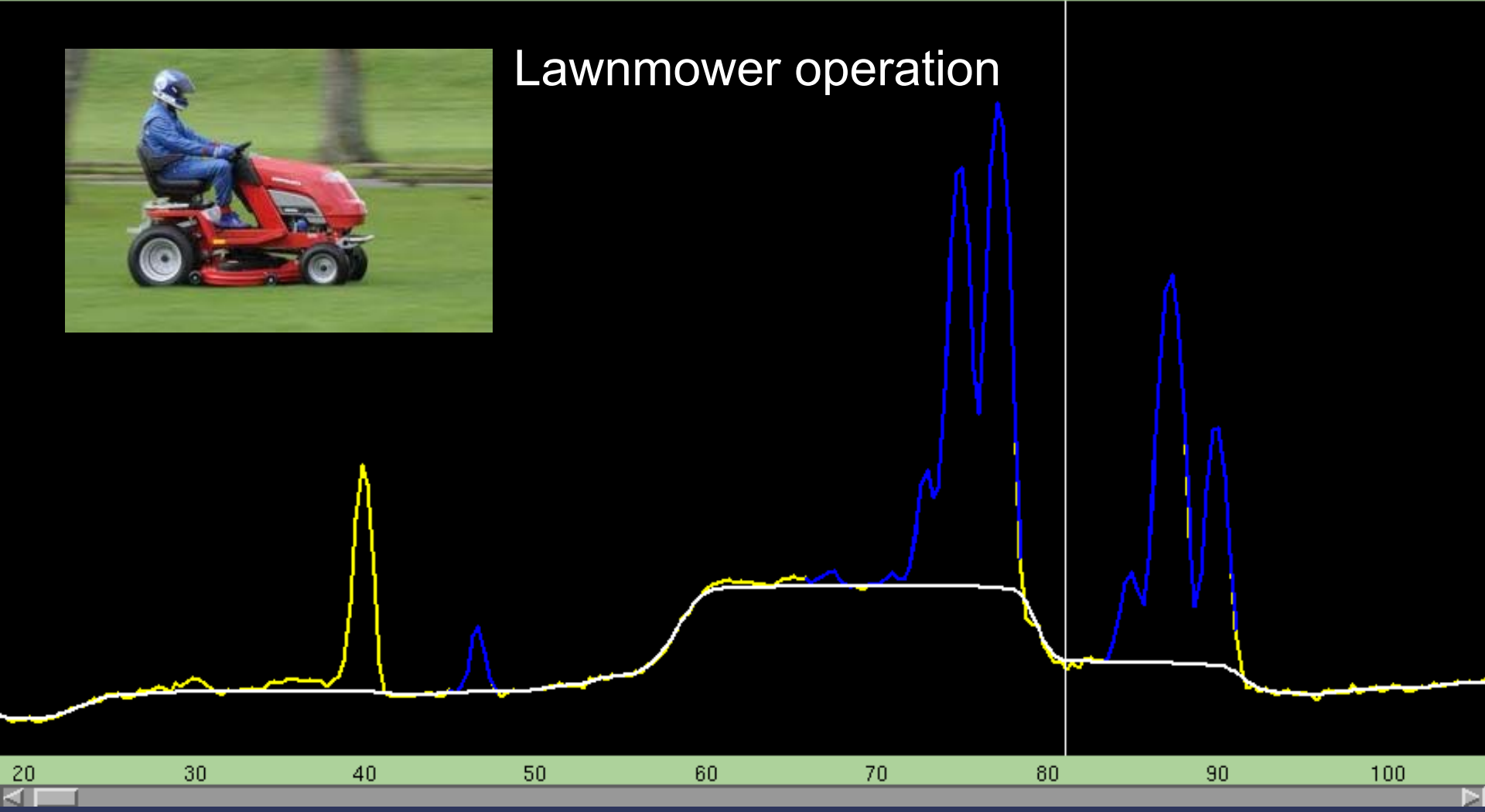
Lawnmower operation



FOI

Lawnmower operation

FOI

Lawnmower operation

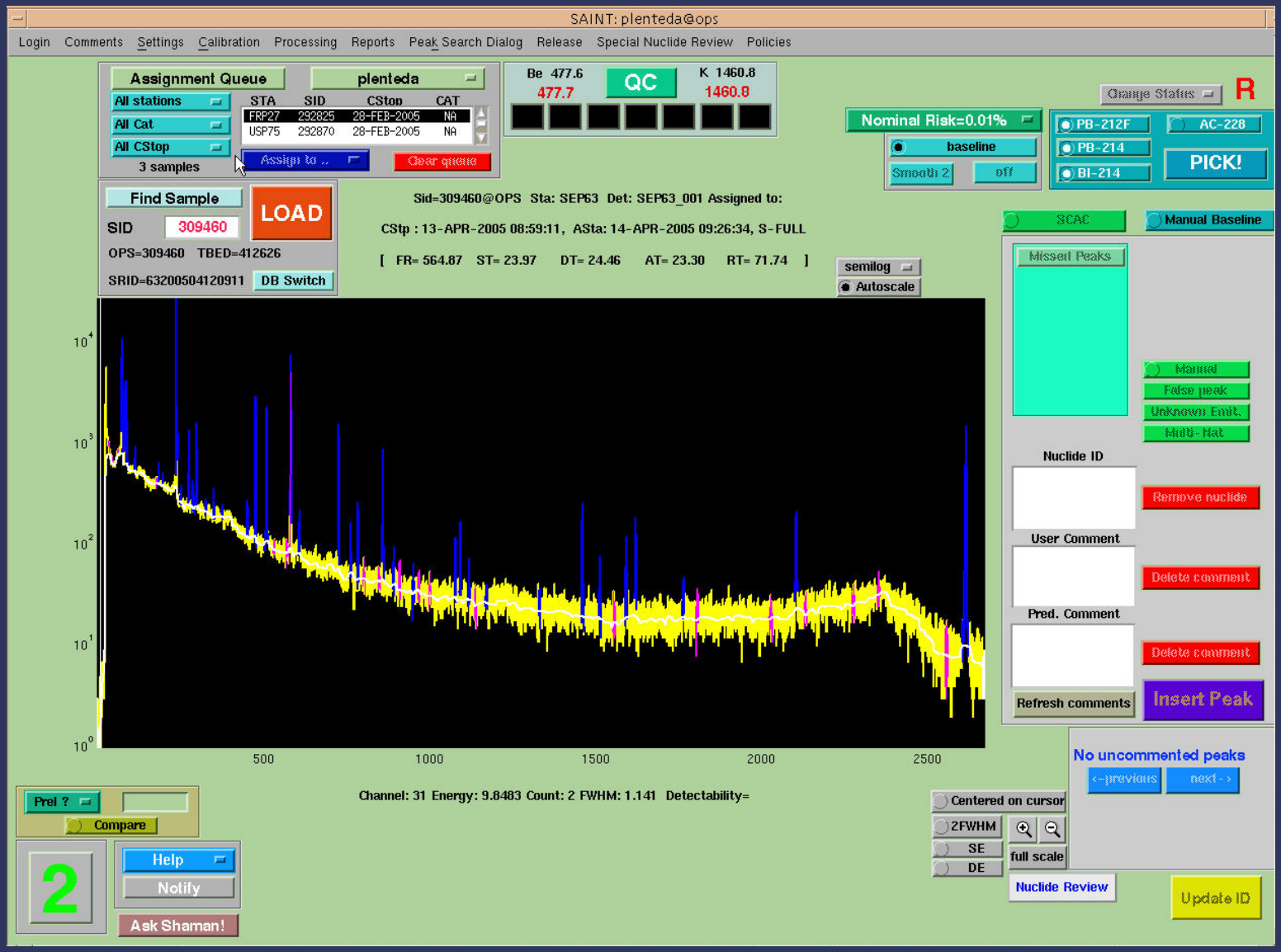
FOI

Lawnmower operation

FOI

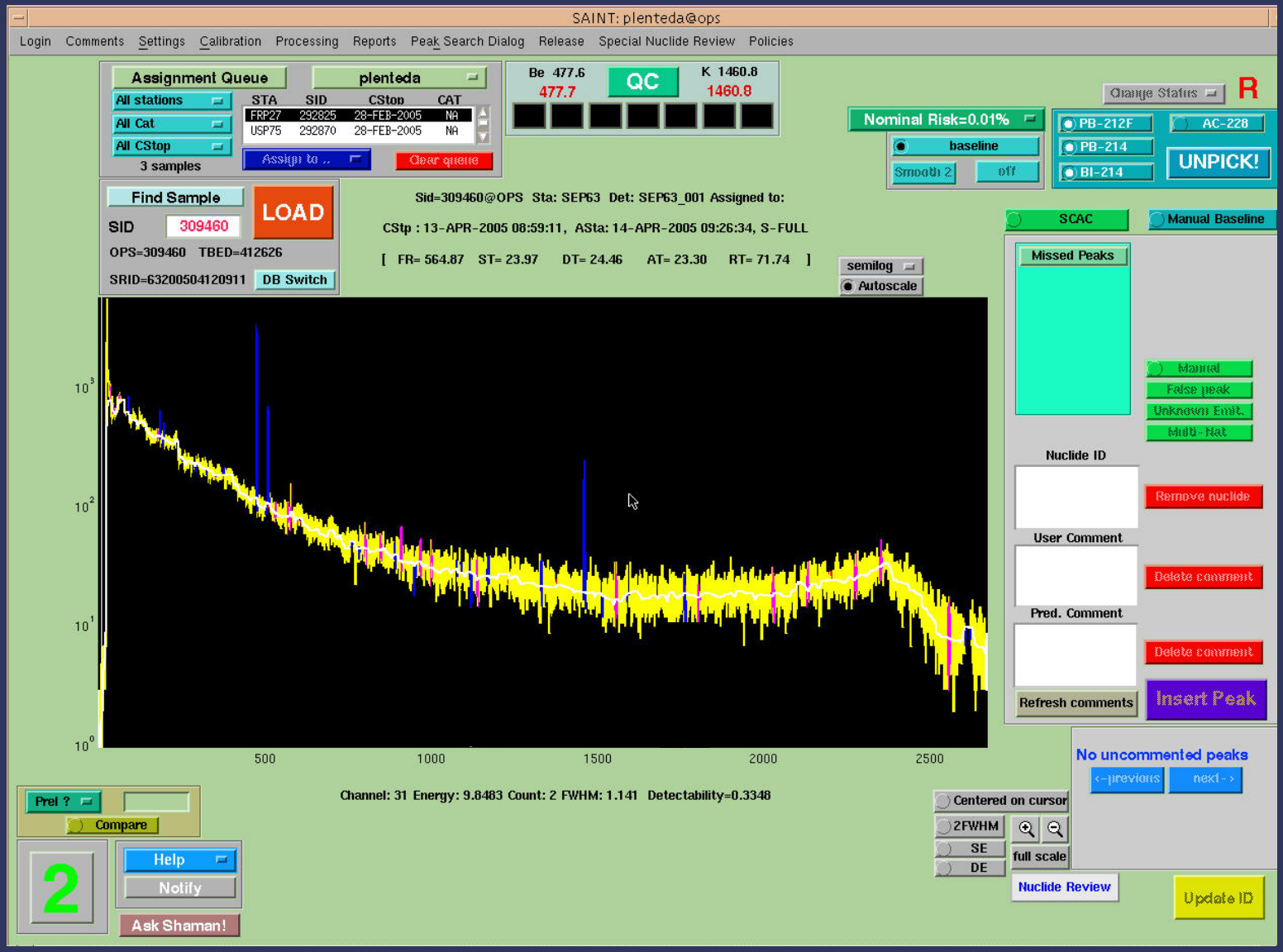
Lawnmower operation

FOI



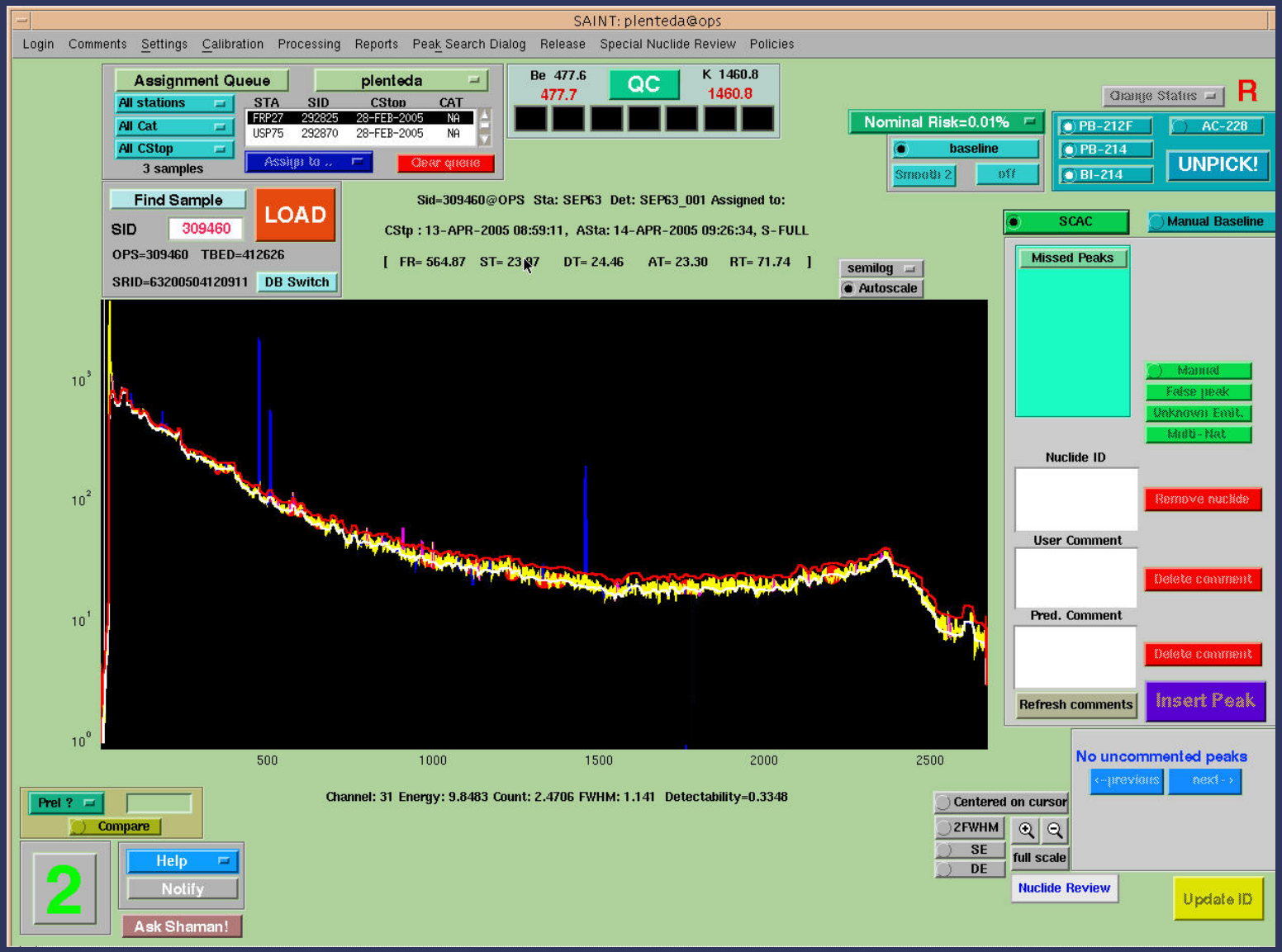
FOI

SAINT opening window



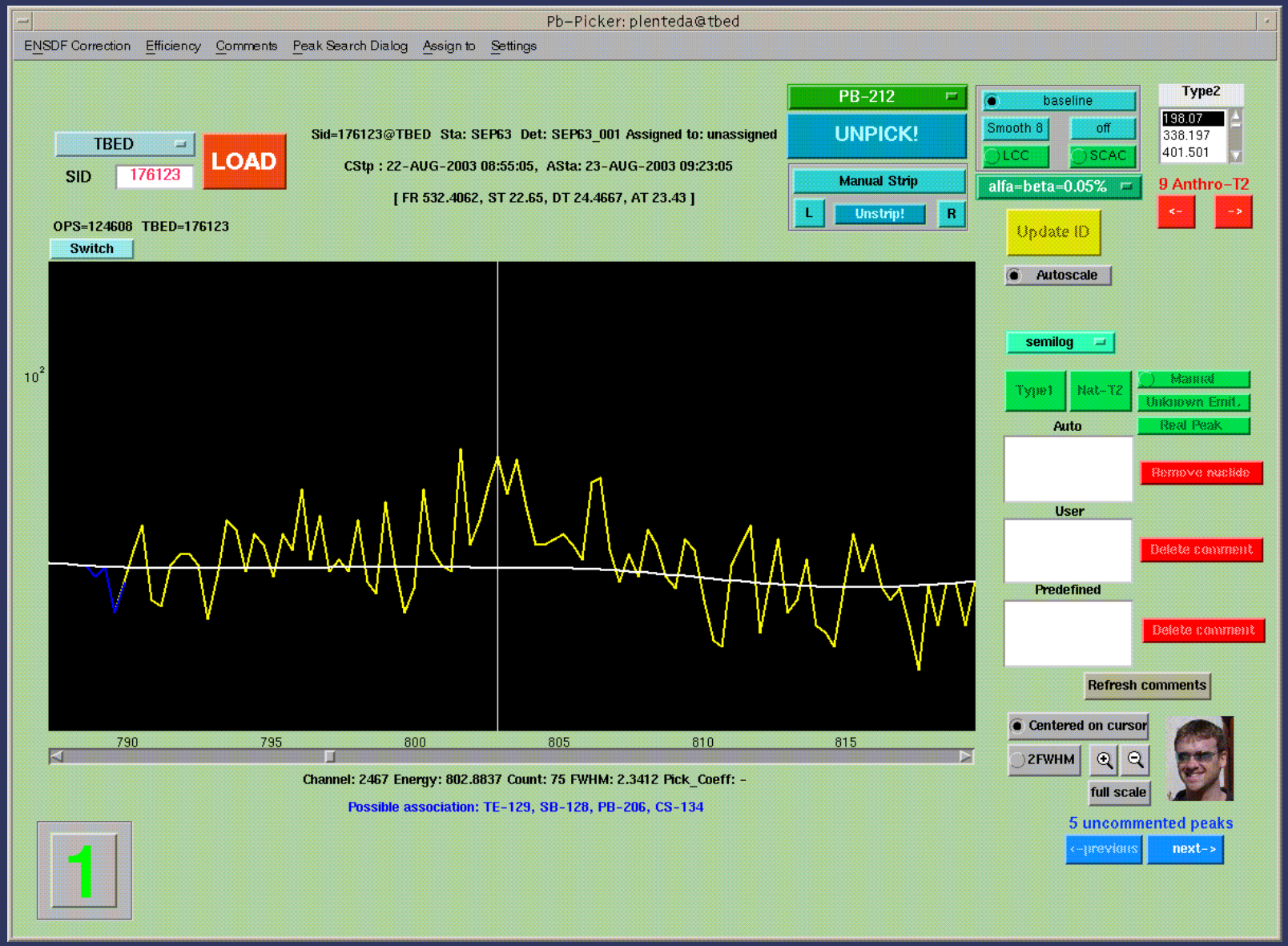
FOI

SAINT spectrum picked



FOI SAINT SCAC-LCC

FOI SAINT SCAC-LCC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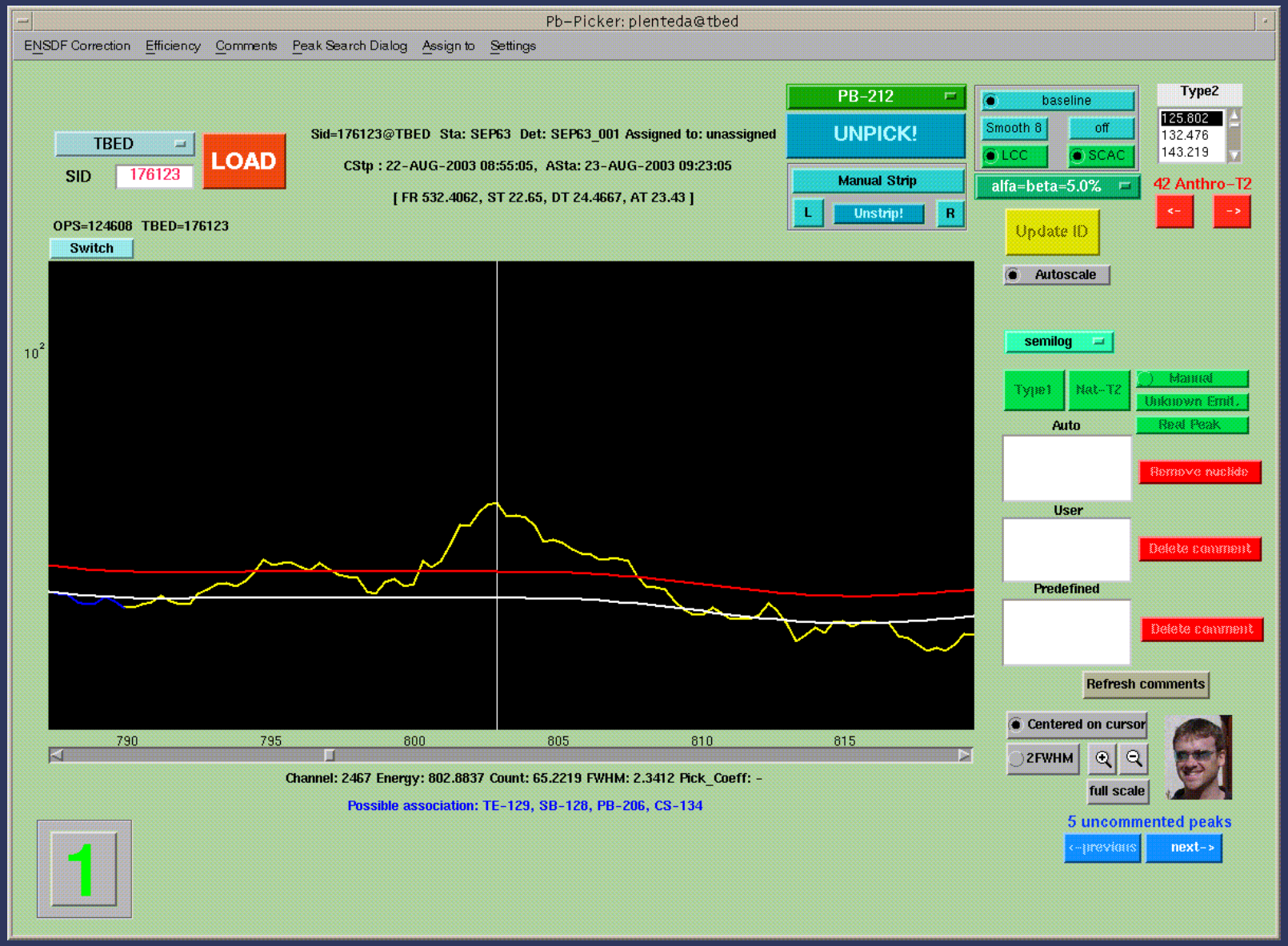
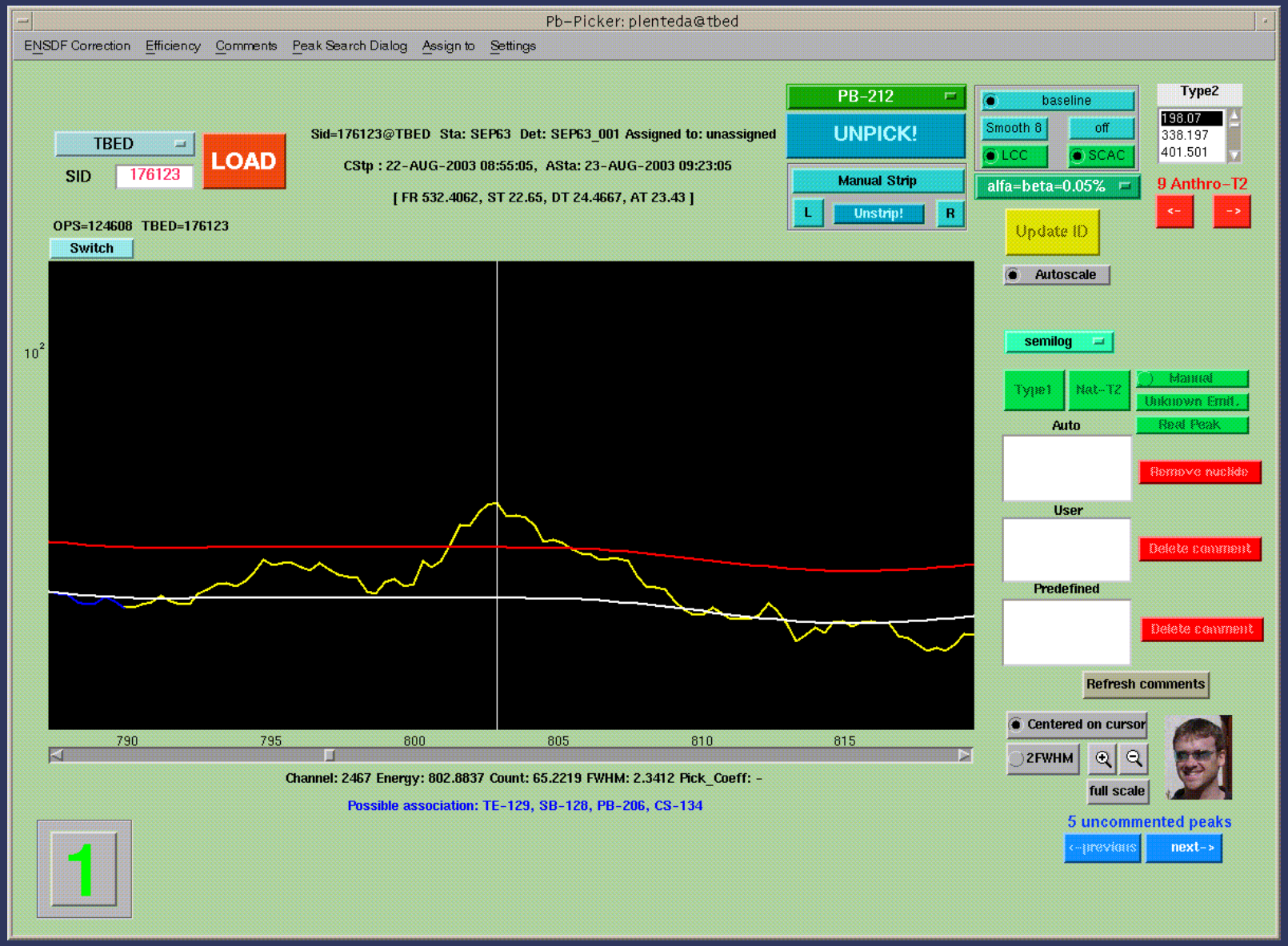
ENSDF Correction
Efficiency
Comments
Peak Search Dialog
Assign to
Settings
TBED
SID
176123
LOAD
Sid=176123@TBED Sta: SEP63 Det: SEP63_001 Assigned to: unassigned
CStp : 22-AUG-2003 08:55:05, ASta: 23-AUG-2003 09:23:05
[FR 532.4062, ST 22.65, DT 24.4667, AT 23.43]
OPS=124608 TBED=176123
Switch
PB-212
UNPICK!
Manual Strip
L
Unstrip!
R
baseline
Smooth 8
off
LCC
SCAC
alfa=beta=0.05%
Update ID
Autoscale
Type2
198.07
338.197
401.501
9 Anthro-T2
<-
->
semilog
Type1
Nat-T2
Manual
Unknown Emit.
Real Peak
Auto
Remove nuclide
User
Delete comment
Predefined
Delete comment
Refresh comments
Centered on cursor
2FWHM
full scale
5 uncommented peaks
<-previous
next->
790
795
800
805
810
815
Channel: 2467 Energy: 802.8837 Count: 75 FWHM: 2.3412 Pick_Coeff: -
Possible association: TE-129, SB-128, PB-206, CS-134
1

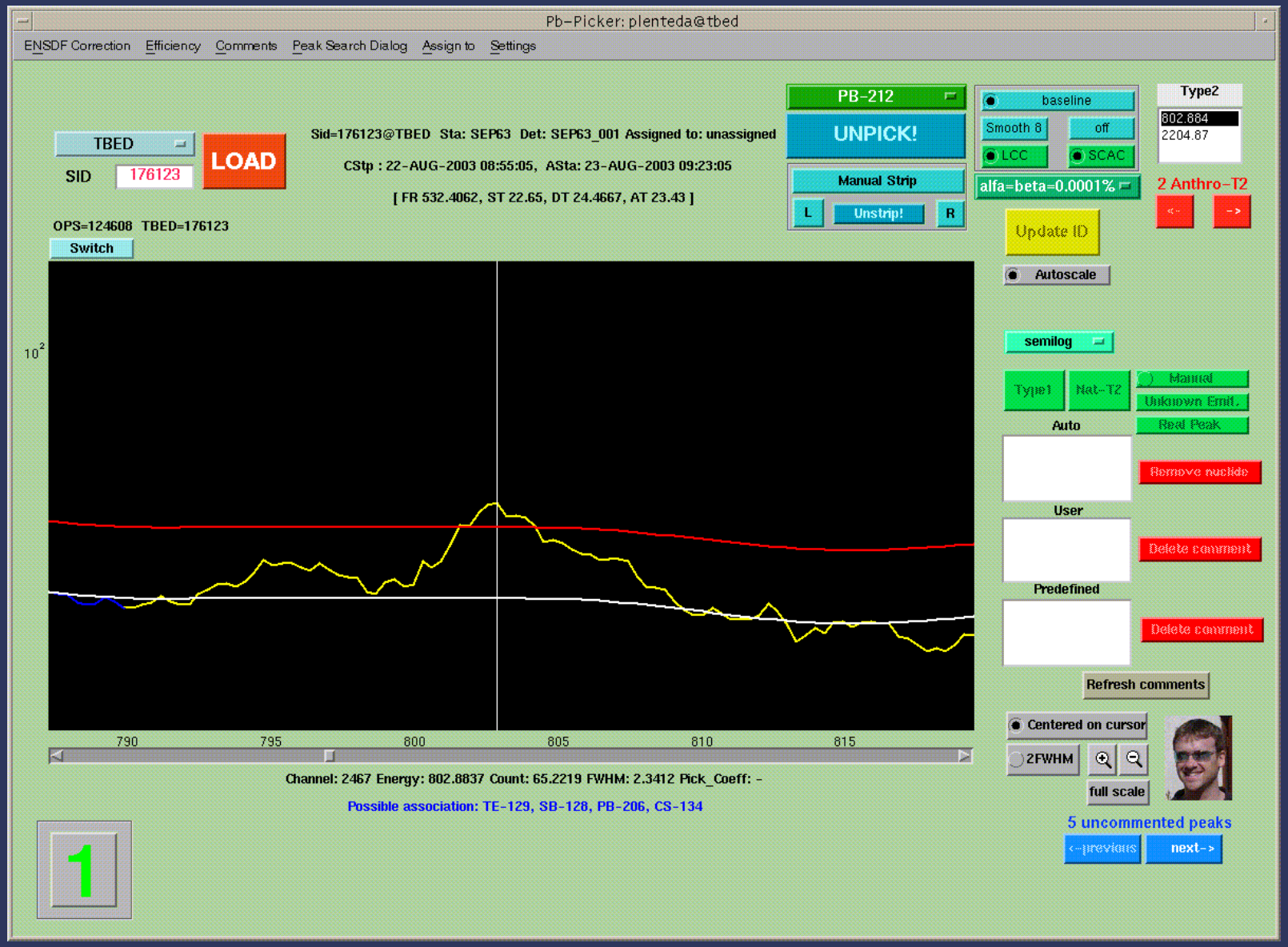
FOI


Pb-Picker: plenteda@tbed
ENSDF Correction
Efficiency
Comments
Peak Search Dialog
Assign to
Settings
TBED
SID
176123
LOAD
Sid=176123@TBED Sta: SEP63 Det: SEP63_001 Assigned to: unassigned
CStp : 22-AUG-2003 08:55:05, ASta: 23-AUG-2003 09:23:05
[FR 532.4062, ST 22.65, DT 24.4667, AT 23.43]
OPS=124608 TBED=176123
Switch
PB-212
UNPICK!
Manual Strip
L
Unstrip!
R
baseline
Smooth 8
off
LCC
SCAC
alfa=beta=5.0%
Type2
125.802
132.476
143.219
42 Anthro-T2
<-
->
Update ID
Autoscale
semilog
Type1
Nat-T2
Manual
Unknown Emit.
Real Peak
Auto
Remove nuclide
User
Delete comment
Predefined
Delete comment
Refresh comments
Centered on cursor
2FWHM
full scale
5 uncommented peaks
<-previous
next->
790
795
800
805
810
815
Channel: 2467 Energy: 802.8837 Count: 65.2219 FWHM: 2.3412 Pick_Coeff: -
Possible association: TE-129, SB-128, PB-206, CS-134
1

FOI


Pb-Picker: plenteda@tbed
ENSDF Correction
Efficiency
Comments
Peak Search Dialog
Assign to
Settings
TBED
SID
176123
LOAD
Sid=176123@TBED Sta: SEP63 Det: SEP63_001 Assigned to: unassigned
CStp : 22-AUG-2003 08:55:05, ASta: 23-AUG-2003 09:23:05
[FR 532.4062, ST 22.65, DT 24.4667, AT 23.43]
OPS=124608 TBED=176123
Switch
PB-212
UNPICK!
Manual Strip
L
Unstrip!
R
baseline
Smooth 8
off
LCC
SCAC
alfa=beta=0.05%
Update ID
Autoscale
Type2
198.07
338.197
401.501
9 Anthro-T2
<-
->
semilog
Type1
Nat-T2
Manual
Unknown Emit.
Real Peak
Auto
Remove nuclide
User
Delete comment
Predefined
Delete comment
Refresh comments
Centered on cursor
2FWHM
full scale
5 uncommented peaks
<-previous
next->
790
795
800
805
810
815
Channel: 2467 Energy: 802.8837 Count: 65.2219 FWHM: 2.3412 Pick_Coeff: -
Possible association: TE-129, SB-128, PB-206, CS-134
1

FOI


Pb-Picker: plenteda@tbed
ENSDF Correction
Efficiency
Comments
Peak Search Dialog
Assign to
Settings
TBED
SID
176123
LOAD
Sid=176123@TBED Sta: SEP63 Det: SEP63_001 Assigned to: unassigned
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OPS=124608 TBED=176123
Switch
PB-212
UNPICK!
Manual Strip
L
Unstrip!
R
baseline
Smooth 8
off
LCC
SCAC
alfa=beta=0.0001%
Update ID
Autoscale
Type2
802.884
2204.87
2 Anthro-T2
semilog
Type1
Nat-T2
Manual
Unknown Emit.
Real Peak
Auto
Remove nuclide
User
Delete comment
Predefined
Delete comment
Refresh comments
Centered on cursor
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full scale
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1

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Thank you

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How do we decide what risks we should take?

1. The PEAKMAKER and PLATEMAKER Mathematica programs provide interfaces between mathematics and what we think we see on the display.

2. Gain experience. Murray has worked on this for a while in Romano's L_C-GUI and I think I hear Murray vote for an α between 0.0001% and 0.001%.

3. To keep the quality pressure on the stations everything stays the same if the SCA width is set to 1.25 FWHM, m to ◎ and α to 0.05%, when the barium-140 detection limit is analyzed.

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The “Lawnmower” algorithm

CTBTO PREPARATORY COMMISSION

To solve the first problem we should “cut” as most we can the spectrum peaks before smoothing. The following algorithm can be used:

For each channel j we define a channel interval $j - \delta^1$, $j + \delta^2$ where δ^1 and δ^2 are the equivalent in channels of 2*FWHM(j) .
If the channel j happens to be the one with maximum counts in this interval, it is a good candidate to be the centroid of a potential peak.
In this case the original spectrum in the selected interval is replaced with a straight line from $j - \delta^1$ to $j + \delta^2$.
After 2 o 3 times of application of this algorithm all the peaks will be cut out.

Application

Coupling the smoothing and the Lawnmower algorithm we have a very good baseline for all the energies with the exception of some structures like saw teeth where only the smoothing is applied. Compton edges are preserved.

In the case of multiplets the width of the structure is larger than FWHM, therefore the loop smooth-Lawnmower will give a final structure of a plateau far from the right baseline. To solve this problem, on the X-rays region, the Lawnmower algorithm is applied many times before smoothing.

Application: the recipe

Due to the large amount of multiplets in the X-rays region I distinguish two regions:

1) 0 - 110 keV

2) 110 - E_{max}

1) 2 loops with 1 smoothing and 80 Lawnmowers each.

2) 4 loops with 1 smoothing and 4 Lawnmowers each.

The smoothing

The smoothing algorithm is the most straightforward way to calculate the baseline, it consists in setting the counts to a given channel as the average of the neighbouring channels for a given interval width.

This algorithm, applied in the baseline calculation for gamma spectra, works fine in the absence of peaks structure, since the baseline should not consider the peak counts but only the ones coming from the background.

The baseline itself should follow the shape of certain spectrum structures not recognizable as peaks like Compton edges or saw teeth from (n,n’) reactions.

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