Pu Lx spectroscopy in the presence of other radioisotopes

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GammaSem Proceedings

A Nordic seminar for users of gamma spectrometry

Kjeller 28-29 September 2010

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3 Norwegian Radiation Protection Authority, Norway
4 Radiation and Nuclear Safety Authority, Finland
5 Risø National Laboratory for Sustainable Energy, Denmark
6 Icelandic Radiation Safety Authority, Iceland
7 Swedish Defence Research Agency, Sweden
8 Malmö University Hospital, Lund University, Sweden

November 2010

Abstract

The project GammaSem was proposed to the NKS in 2008. The aim of the project was to arrange two seminars for users of gamma spectrometry, in 2009 and 2010. The seminars were meant to provide a forum for discussions and sharing of information on practical issues concerning gamma spectrometry and initiate a network of gamma spectrometry users in the Nordic countries. Such a Nordic network should strengthen the collaboration between laboratories and improve all participants' competence in practical gamma spectrometry.

Both seminars' focus was practical challenges met by the users themselves, rather than theoretical matters. Scientists and users of gamma spectrometry from all five Nordic countries were invited to the seminar, as well as scientist from the Baltic countries. A total of 65 people signed up for GammaSem 2010; representing 30 different universities, commercial companies, research institutes and authorities.

The working group concept as presented at last year's GammaSem, has not worked out as intended. The reason for this is probably because most of the laboratories that signed up to join the working groups, signed up because they wanted to learn more about the different subjects. In combination with the fact that no funding was made available for the working groups, it was difficult to establish goals on what to achieve. None of the working groups applied for funding from the NKS (or elsewhere) to establish separate projects.

There is a big need for more cooperation and for training within the field of gamma spectrometry. This fact has been proved through these two seminars, both by the many different topics that have been discussed, but also by the huge interest for participating in the suggested series of workshop. The GammaSem seminars have thus provided a much welcomed starting point for a broader Nordic collaboration.

Key words

gamma spectrometry

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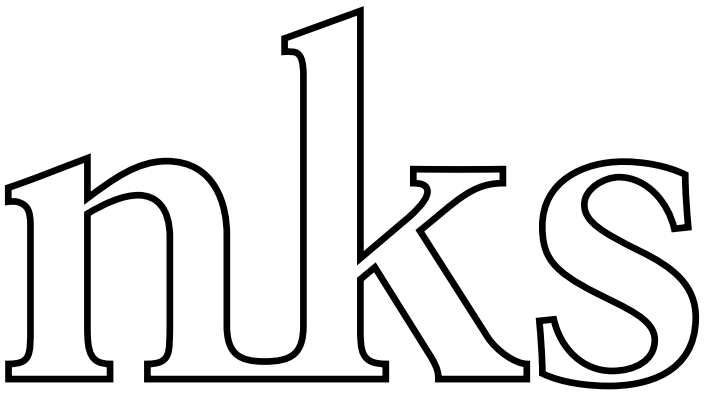

Elisabeth Strålberg (ed.), Katrine Berg, Mark Dowdall, Knut Eitrheim, Seppo Klemola, Sven P. Nielsen, Sigurður Emil Pálsson, Henrik Ramebäck, Christopher Rääf, Per Roos and Morten Sickel

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Introduction

During the last years, there has been little contact or collaboration between gamma spectrometry users in the Nordic countries. As the Nordic countries are small, there are quite few people involved in gamma spectrometry in each country and the users work most of the time in their own laboratory, with minor contact with other Nordic colleagues. Todays increasing demand for quality assurance and accreditation makes collaboration between laboratories even more relevant.

The project GammaSem was therefore proposed to the NKS in 2008. The aim of the project was to arrange two seminars for users of gamma spectrometry, in 2009 and 2010. The seminars were meant to provide a forum for discussions and sharing of information on practical issues concerning gamma spectrometry and initiate a network of gamma spectrometry users in the Nordic countries. Such a Nordic network should strengthen the collaboration between laboratories and improve all participants' competence in practical gamma spectrometry.

Both seminars' focus was practical challenges met by the users themselves, rather than theoretical matters. Scientists and users of gamma spectrometry from all five Nordic countries were invited to the seminar, as well as scientist from the Baltic countries. A total of 65 people signed up for GammaSem 2010; representing 30 different universities, commercial companies, research institutes and authorities. For a complete list of participants see attachment 1.

The first seminar was held in September 2009. The proceedings from this seminar are available as a NKS report (NKS-212).

This report is a description of the second seminar, held in September 2010.

GammaSem 2009

During the first GammaSem seminar several key issues for follow-up were identified and working groups for addressing the identified problems were established. The groups are listed at the next page (subgroup leaders highlighted in cursive letters, the rest of the participating organisations follow). At the seminar it was decided that the topics for the working groups should form the basis for the seminar in 2010 where the groups should be invited to present the results of their work and ideas/solutions to the problems. This was thought to ensure that the identified key issues were not forgotten but followed up, and hopefully lead to solutions that will increase the performance of the individual laboratories. The number of participants of the GammaSem activity was therefore expanded to include the working group coordinators.

At the seminar in 2009 it was also decided that the participants of the GammaSem activity should organise web sites for posting relevant information and discussion forums. This would make it easier to contact Nordic colleagues on issues related to gamma spectrometry

Working groups established at GammaSem 2009:

Uncertainties and detections limits
FOI, Lund University, TVO, ICT, SKB, STUK, RISØ, Ringhals NPP, Forsmarks Kraftgrupp AB, Icelandic Radiation Safety Authority, Danish Decommissioning

True coincidence summing corrections
IFE Kjeller, NRPA, RISØ, SIS, NRPA Tromsø, Icelandic Radiation Safety Authority, Ringhals NPP, FOI, OKG AB

Monte Carlo simulations and efficiency transfer
NRPA, Göteborg University, STUK, FOI, Icelandic Radiation Safety Authority

Absorption (density corrections and geometries)
IFE Halden, Lund University, ICT, IFE Kjeller

Mobile gamma spectrometry systems
NRPA, IFE Kjeller, Danish Decommissioning, FOI, DEMA

Nuclear forensics (on special samples and special parts of the spectra)
RISØ, NRPA, STUK, FOI, IFE Kjeller, Danish Decommissioning

GammaSem 2010

The agenda for GammaSem 2010 is included as attachment 2 of this report.

The seminar was officially opened by research director Brit S. Farstad of IFEs sector for Nuclear Technology and Physics.

Lars-Erik De Geer from the Swedish Defence Research Agency was invited to give the opening presentation of the seminar. His presentations with the title "*True Coincidences and a Decent Currie*" covered aspects of true coincidence summation corrections and developments in this field accomplished at the Provisional Technical Secretariat (PTS) for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) in Vienna. The presentation also included some considerations regarding Currie's detection criteria in gamma spectroscopy. Lars-Erik De Geer's presentation is found in attachment 3.

Attachment 4 includes the *Book of abstracts* made available for the participants at the seminar. The full presentations are available at the NKS website.

The original plan was to include presentations from all six working groups to the agenda. However, only two out of six working groups gave presentations of the work accomplished during the last year.

- **Working group on uncertainties and detections limits:** A questionnaire regarding application of combined uncertainty calculation and budgeting and use of detection limits for gamma ray spectrometry were distributed to laboratories in the Nordic and Baltic countries. The responses showed that not all laboratories take the uncertainties associated with counting efficiency and calibration standard into consideration. Even less laboratories consider the uncertainty of the density and coincidence corrections. Regarding detection limits, the responses showed that a flora of different expressions for the detection limit is used. There is almost no use of critical limits; for any laboratory commissioned with exemption measurements this is an urgent problem which needs to be addressed. As expected, there are two dominating softwares for gamma spectrometry in use in the Nordic and Baltic countries. A question that should be asked is whether we are relying too heavily on their default expressions for detection limits.

- **True coincidence summing corrections (TCC):** The working group agreed on the following plan during spring 2010:
    - Primary goal of the TCC GammaSem Working group:
        1. Describe when TCC is needed.
        2. How large error is produced if TCC is not used.
        3. Produce guidelines on how to use TCC (for users of the major softwares Genie and GammaVision).
    - How to achieve this?
        1. Write a short "guidance" on when TCC is needed → labs already using TCC.
        2. Test the TCC calibration procedure presented by IRSA on GammaSem 2009 → labs using GammaVision.
        3. Test TCC calibration for Genie → labs using Genie.
        4. Intercomparison test, with and without TCC → all labs in TCC working group.

  There has been little or no response from the working group participants during the year that has passed. It is believed that most of the group members signed up because they wanted to learn more about TCC and eventually implement TCC in their own laboratories. Also, there were no funding made available for this work, and the group therefore agreed that the work should be accomplished only by e-mail communication. This has led to the fact that almost nothing has been done in the TCC working group. Some work has however been done: Information on the use of TCC has been compiled by IRSA and some tests on TCC in GammaVision have been done at IFE. IRSA has used the TCC calibration in GammaVision in two NPL intercomparison exercises and achieved good results (100 % score). The tests performed at IFE however, showed large discrepancies from known true values. IFE used a low-energy, n-type detector for the tests, and even though Ortec states that the TCC calibration can be used on both p- and n-type detectors, this might not be the case.

  IFE also participated at ALMERA's workshop on coincidence summing and geometry correction in gamma spectrometry. A report from this workshop was

given in a separate presentation at the seminar. IFE also intended to attend an Ortec course on TCC in USA. However, because too few participants signed up for the course, the course was cancelled. This course is the only advanced course offered by Ortec that includes TCC.

The last day of the seminar, IRSA also gave a presentation of the GammaForum and GammaWiki web sites:

- **GammaForum**, a web based discussion forum where ideas within working groups could be presented and developed (https://www.gr.is/forum/GammaForum/). This site has not been used at all, only one person registered as a user. IRSA suggested that this site should be shut down, unless argument to the contrary should be presented during the general discussion at the end of the seminar.

- **GammaWiki**, a wiki based web where output from the working groups could be presented, as well as other relevant material (https://www.gr.is/wiki/GammaWiki/). At this site no material has been put in by anyone apart from webmaster. Some material has been received from some GammaSem participants. Very positive comments have however been given by potential users of the web site. As GammaWiki does not depend on active use, its usefulness increases as more material is put in. The question asked to the GammaSem participants is therefore: Should GammaWiki be continued?

At the end of the seminar, there was a general discussion and evaluation of the GammaSem seminars, the working group concept, reporting and future work. The discussion was lead by the NKS-B Programme Manager Justin Gwynn and divided into three sections:

1. GammaWiki / GammaForum
2. Evaluation of the working groups / working group concept
3. Future work – continuation of GammaSem

1. GammaWiki / GammaForum

It was agreed that the GammaForum web site should be closed. The number of potential users in the Nordic countries is too small for such a forum to survive. A French forum for gamma spectrometry has experienced the same, and will shut down if the use of the forum does not increase.

GammaWiki does not depend on active use, the information will still be there even if the number of users are low. The costs for keeping the site alive will mainly be working hours for administration and updates, and not direct costs for data storage capacity. It was suggested that the GammaWiki could be included in another already existing wiki for all nuclear sciences. This would increase the number of potential users of the wiki and thereby increase the usefulness of such a web site. It was also pointed out that a discussion forum can be included in the GammaWiki.

However, it seemed to be a wish among the GammaSem participants to keep the GammaWiki as it is. The administrator and working group leaders will continue to include relevant information, e.g links to databases, softwares etc, and as more information is included, the GammaWiki web page will be a useful tool for gamma spectrometry users.

2. Evaluation of the working groups / working group concept

The working group concept as presented at last year's GammaSem, has not worked out as intended. The reason for this is probably because most of the laboratories that signed up to join the working groups, signed up because they wanted to learn more about the different subjects. In combination with the fact that no funding was made available for the working groups, it was difficult to establish goals on what to achieve. None of the working groups applied for funding from the NKS (or elsewhere) to establish separate projects.

It was however pointed out that even if it seems like little or nothing has been done in the working groups, the focus on these subjects at GammaSem 2009 has made laboratories more aware of the problems and also possible solutions.

It was a wish among the GammaSem participants that relevant courses should be available in the Nordic countries, e.g. it should not be necessary to go the US to learn about true coincidence summation corrections in GammaVision.

3. Future work – continuation of GammaSem

It was suggested that, rather than arranging a third GammaSem, a series of workshops covering relevant subjects in gamma spectrometry could be arranged in 2011. The workshop participants could be divided into groups according to software and bring their own computers to learn to solve different problems themselves. The workshop could last 1-3 days covering 2-4 different subjects.

When the question was raised, a majority of the GammaSem participants expressed positive interest in participating is such a series of workshops. True coincidence summation correction, uncertainties and detections limits, databases and absorption were suggested as relevant subjects.

It was agreed that a third GammaSem could be arranged after such a series of workshops, maybe in 2012 or 2013.

An application to the NKS for funding for these workshops should be submitted before the next NKS deadline (15 October). IRSA volunteered to lead the work with the application, assisted by IFE and FOI.

Concluding remarks

There is a big need for more cooperation and for training within the field of gamma spectrometry. This fact has been proved through these two seminars, both by the many different topics that have been discussed, but also by the huge interest for participating in the suggested series of workshop. The GammaSem seminars have thus provided a much welcomed starting point for a broader Nordic collaboration.

Most importantly, the participants agreed that the seminars have been successful in providing a forum not otherwise present in the Nordic countries. With this in mind the organising committee strongly recommends the NKS to grant funding for future applications covering different subjects within the field of gamma spectrometry, and especially that funding is provided for the suggested series of workshop to be held in 2011.

Attachment 1: List of participants

Ala-Heikkilä, Jarmo	Aalto University School of Science and Technology, Finland
Anttila, Kari	Ringhals AB, Section of Radiation Physics, Sweden
Baranwal, Vikas	Geological Survey of Norway
Bjerk, Trygve	Institute for Energy Technology, Norway
De Geer, Lars-Erik	Swedish Defence Research Agency
Drefvelin, Jon	Norwegian Radiation Protection Authority
Eitrheim, Knut	Institute for Energy Technology, Norway
Enger, Elin	Norwegian Defence Research Establishment
Englund, Sofie	OKG AB, Sweden
Fredriksen, Karsten	Nerliens Meszansky AS
Gundersen, Eirik	Heco Laboratorieutsyr
Gwynn, Justin	NKS
Gäfvert, Torbjörn	Norwegian Radiation Protection Authority
Haugen, Ann-Helen	Institute for Energy Technology, Norway
Henell, Eva	OKG AB, Sweden
Hjellum, Gro Elisabeth	Algeta ASA, Norway
Ho, Tung Si	Institute for Energy Technology, Norway
Holm, Peter	OKG AB, Sweden
Hunnes, Iris	Algeta ASA, Norway
Isakar, Kadri	Radiation Safety Department of Environmental Board, Estonia
Isaksson, Stefan	Gammadata Instrument AB
Jäderström, Henrik	Canberra Solutions AB
Kastlander, Johan	Swedish Defence Research Agency
Klemola, Seppo	Radiation and Nuclear Safety Authority, Finland
Kock, Peder	Dep. of Medical Radiation Physics, Lund University, Sweden
Konnéus, Patrik	Ringhals AB, Section of Radiation Physics, Sweden
Ladderud, Gro Lise	Institute for Energy Technology, Norway
Leppänen, Ari-Pekka	Radiation and Nuclear Safety Authority, Finland
Lind, Ole Christian	Norwegian University of Life Sciences
Lindroth, Axel	Canberra Solutions AB
Markocsan, Daniela	Department of Radiation Physics, Sahlgrenska Academy at Göteborg University, Sweden
Mattila, Aleksi	Radiation and Nuclear Safety Authority, Finland

Mauring, Alexander	Norwegian Radiation Protection Authority
Mehus, Anfinn	Haukeland University Hospital, Norway
Møller, Peter	National Institute of Radiation Protection, Denmark
Møller, Bredo	Norwegian Radiation Protection Authority
Mårtensson, Stefan	Gammadata Instrument AB
Nalbandyan, Anna	Norwegian Radiation Protection Authority
Nelvik, Ronny	Institute for Energy Technology, Norway
Nielsen, Sven	Risø DTU, National Laboratory for Sustainable Energy, Denmark
Nilssen, Johannes	Norwegian Radiation Protection Authority
Nordhei, Camilla	Institute for Energy Technology, Norway
Nygård, Lars	Nerliens Meszansky AS
Omtvedt, Jon Petter	SAFE, University of Oslo, Norway
Pálsson, Sigurður Emil	Icelandic Radiation Safety Authority
Pettersson, Gustav	Studsvik Nuclear AB, Sweden
Pilkyte, Laima	Radiation Protection Centre, Lithuania
Ramebäck, Henrik	Swedish Defence Research Agency
Ramsøy, Tore	Institute for Energy Technology, Norway
Rannemalm, Hanna	Swedish Nuclear Fuel and Waste Management Co
Roos, Per	Risø DTU, National Laboratory for Sustainable Energy, Denmark
Rønning, Jan Steinar	Geological Survey of Norway
Sekse, Tonje	Norwegian Radiation Protection Authority
Sen Gupta, Nalinava	SAFE, University of Oslo, Norway
Sidhu, Rajdeep	Institute for Energy Technology, Norway
Sillanpää, Risto	Teollisuuden Voima OYJ (TVO), Finland
Stavsetra, Liv	Institute for Energy Technology, Norway
Strålberg, Elisabeth	Institute for Energy Technology, Norway
Sværen, Ingrid	Institute of Marine Research, Norway
Syed, Naeem Ul Hasan	Norwegian Radiation Protection Authority
Söderström, Catharina	Swedish Defence Research Agency
Watson, Robin	Geological Survey of Norway
Øvergaard, Sindre	Norwegian Radiation Protection Authority
Aage, Helle Karina	Danish Emergency Management Agency, BRS
Aarnio, Pertti	Aalto University, Department of Applied Physics, Finland

Attachment 2: Agenda GammaSem 2010

Tuesday 28th of September

09.00 - 09.30 **Registration and coffee**

09.30 - 09.35 **Opening of GammaSem 2010 by Brit Farstad,**
Research Director, Nuclear Safety and Reliability, Institute for Energy Technology

09.35 - 09.40 **Practical information**

09.40 - 10.40 **Lars-Erik De Geer**, Swedish Defence Research Agency
True Coincidences and a Decent Currie

10.40 - 11.00 **Open discussion**

11.00 - 11.20 **Jarmo Ala-Heikkilä,** Aalto University School of Science and Technology, Finland
Expert System SHAMAN and Comparison of its Coincidence Correction to KORSUM

11.20 - 11.40 **Henrik Jäderström,** Canberra Solutions
Cascade Summing Corrections with Genie-2000

11.40 - 12.40 **Lunch**

12.40 - 13.00 **Rajdeep Sidhu**, Institute for Energy Technology, Norway
A summary from the ALMERA workshop on coincidence summing and geometry correction in gamma ray spectrometry

13.00 - 13.20 **Vikas Barnawal,** Norwegian Geological Survey
Geological mapping using airborne gamma ray spectrometry

13.20 - 13.40 **Robin Watson,** Norwegian Geological Survey
Mobile gamma ray spectrometry and the efficiency of real-time data processing in describing the natural background signal and highlighting anthropogenic nuclides

13.40 - 14.00 **Helle Karina Aage,** Danish Emergency Management Agency, BRS
Uncertainties in mobile gamma spectrometry

14.00 - 14.20 **Coffee and fruit**

14.20 - 14.40 **Ari-Pekka Leppänen,** Radiation and Nuclear Safety Authority, Finland.
Aspects affecting low-background measurements

14.40 - 15.00 **Pertti Aarnio,** Aalto University, Department of Applied Physics, Finland
LINSSI - Relational Database for Gamma-Ray Spectrometry

15.00 - 15.20 **Robin Watson,** Norwegian Geological Survey
Hand-held gamma spectrometry for assessing radon risk from building aggregates

15.20 - 15.40 **Sigurður Emil Pálsson,** Icelandic Radiation Safety Authority
International co-operation on the analysis of gamma spectra for malevolent radiological situations: NKS-MALRAD and testing the international use of the US TRIAGE system.

15.40 - 16.00 **Open discussion**

18.00 **Joint GammaSem Dinner**
Restaurant Sangliers, Lillestrøm

Wednesday 29th of September

09.00 - 09.20 **Coffee and fruit**

09.20 - 09.40 **Henrik Ramebäck**, Swedish Defence Research Agency
Gamma spectrometric measurement of nuclear materials

09.40 - 10.00 **Elin Enger,** Norwegian Defence Research Establishment
Analysis of samples containing a mixture of biological, chemical, and radiological agents ("mixed samples")

10.00 - 10.20 **Naeem Ul Hasan Syed**, Norwegian Radiation Protection Authority
Verification of fissile materials

10.20 - 10.40 **Per Roos,** National Laboratory for Sustainable Energy at the Technical University of Denmark
Pu Lx spectroscopy in the presence of other radioisotopes

10.40 - 11.00 **Open discussion**

11.00 - 12.00 **Lunch**

12.00 - 12.20 **Sigurður Emil Pálsson,** Icelandic Radiation Safety Authority
Report on GammaWiki as a source of information on gamma spectrometry

12.20 - 12.40 **Elisabeth Strålberg**, Institute for Energy Technology, Norway
Report from GammaSem 2009 Working Group on true coincidence summing corrections

12.40 - 13.00 **Henrik Ramebäck,** Swedish Defence Research Agency
Report from GammaSem 2009 Working Group on uncertainties and detection limits

13.00 - 13.20 **Coffee and fruit**

13.20 - 15.00 **General discussion**
Evaluation of GammaSem 2010 and the WG concept – reporting and future work

15.00 **End of seminar**

Attachment 3

INVITED SPEAKER

Lars-Erik De Geer

FOI, Swedish Defence Research Agency,
Stockholm, Sweden

True coincidences and a Decent Currie

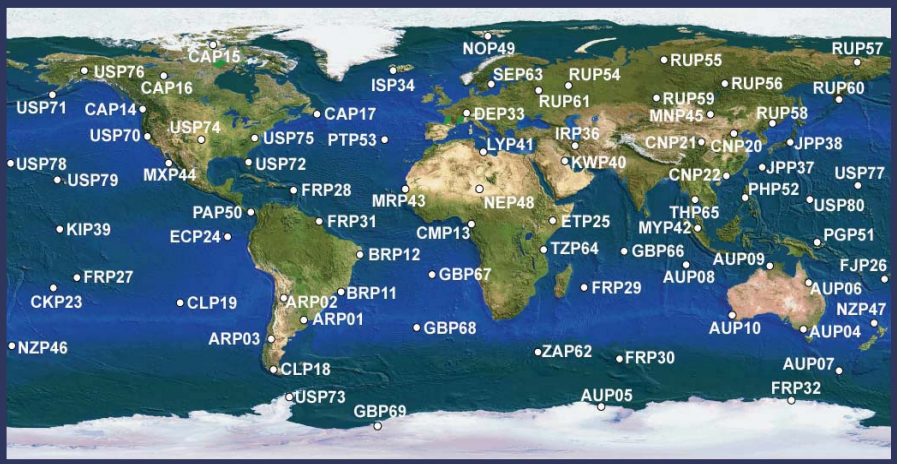
True coincidences and a Decent Currie

Lars-Erik De Geer
FOI, Swedish Defence Research Agency, Stockholm, Sweden
ledg@foi.se

NKS GammaSem2010, Lillestrøm, Norway, 28 September 2010

FOI

Radionuclide Particulate Station Network 79 + 1 TBD

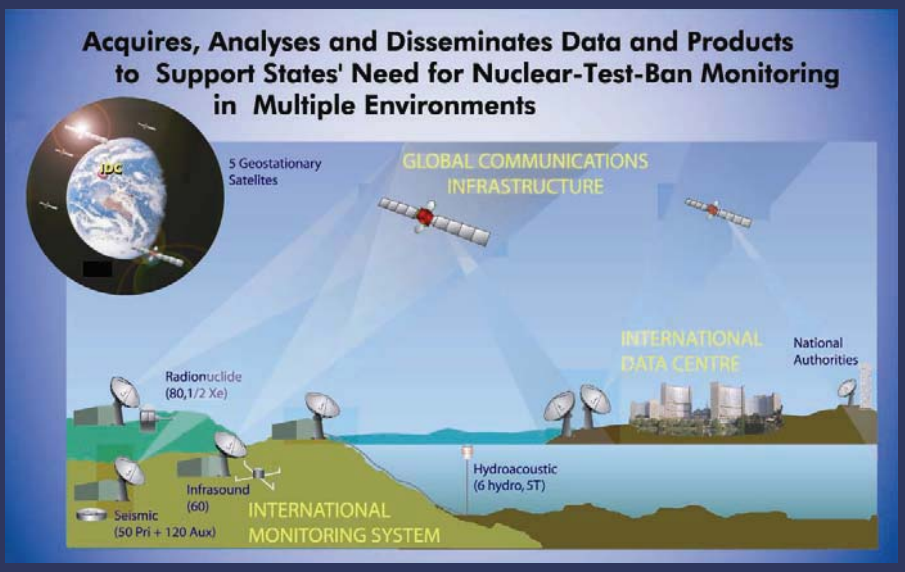


FOI

FOI

SAUNA – Swedish Automatic Unit for Noble gas Acquisition

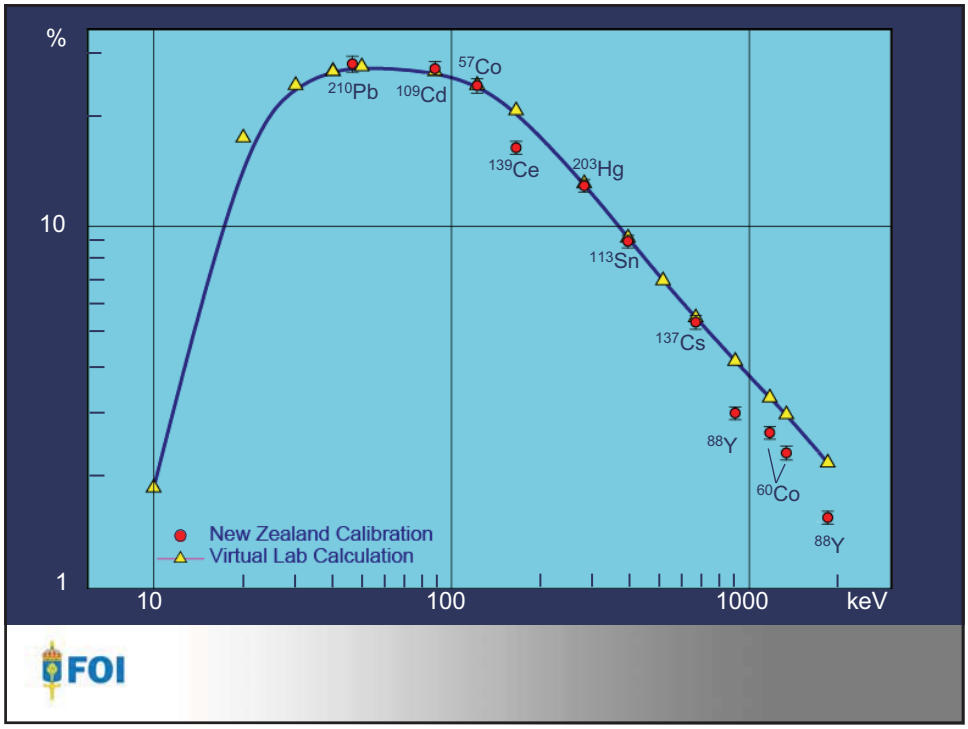
FOI



FOI The CTBT Verification Regime

TCS
True Coincidence Summation

FOI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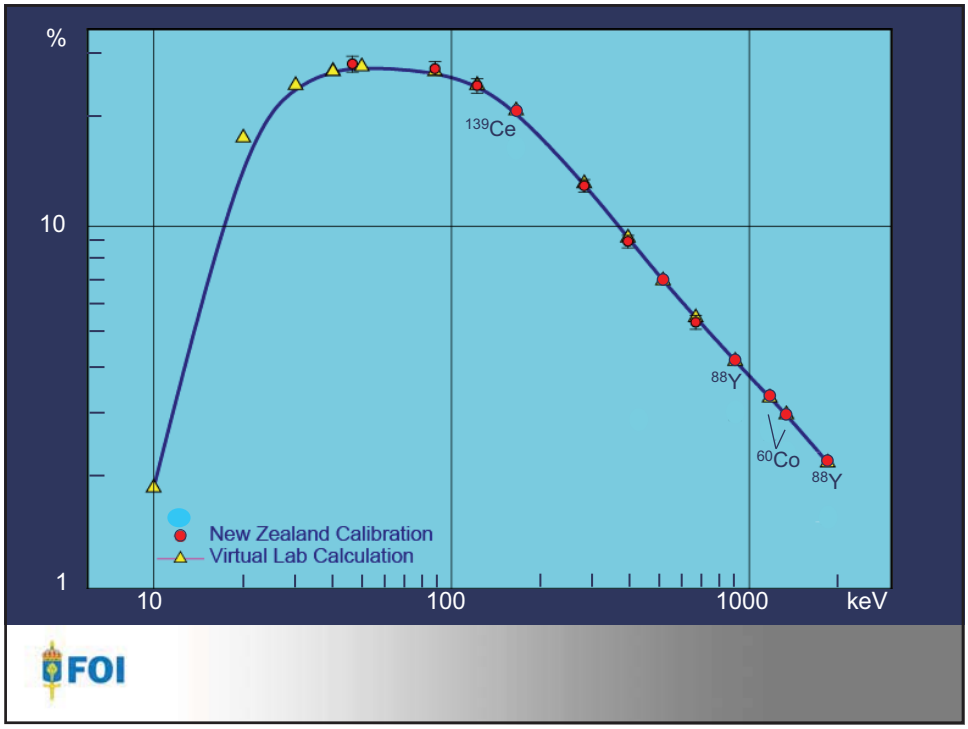
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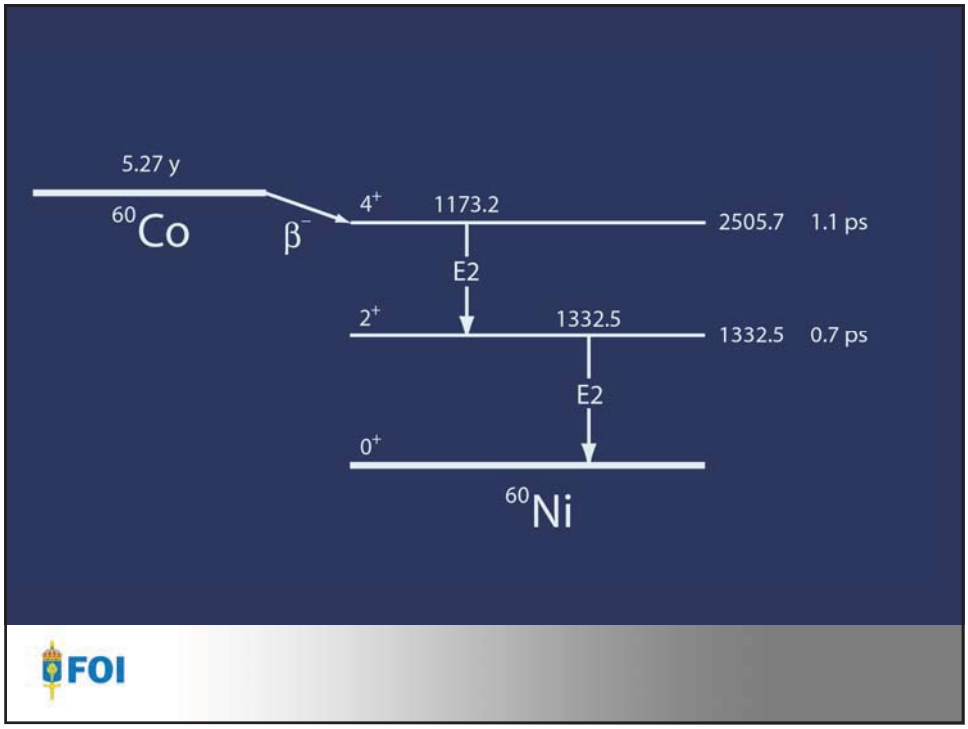
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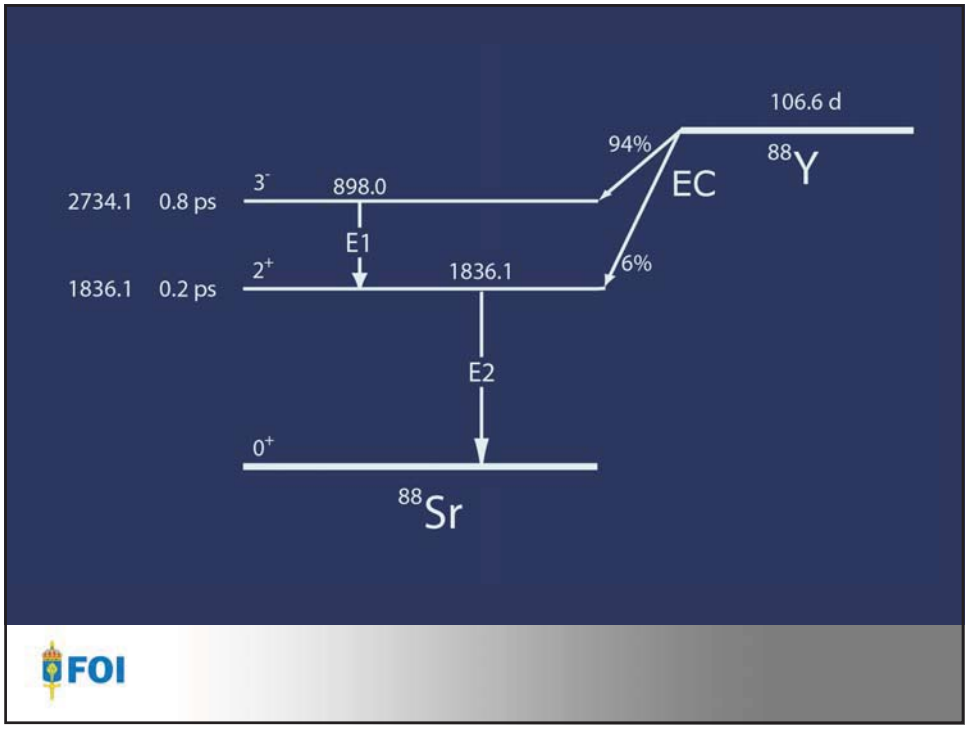
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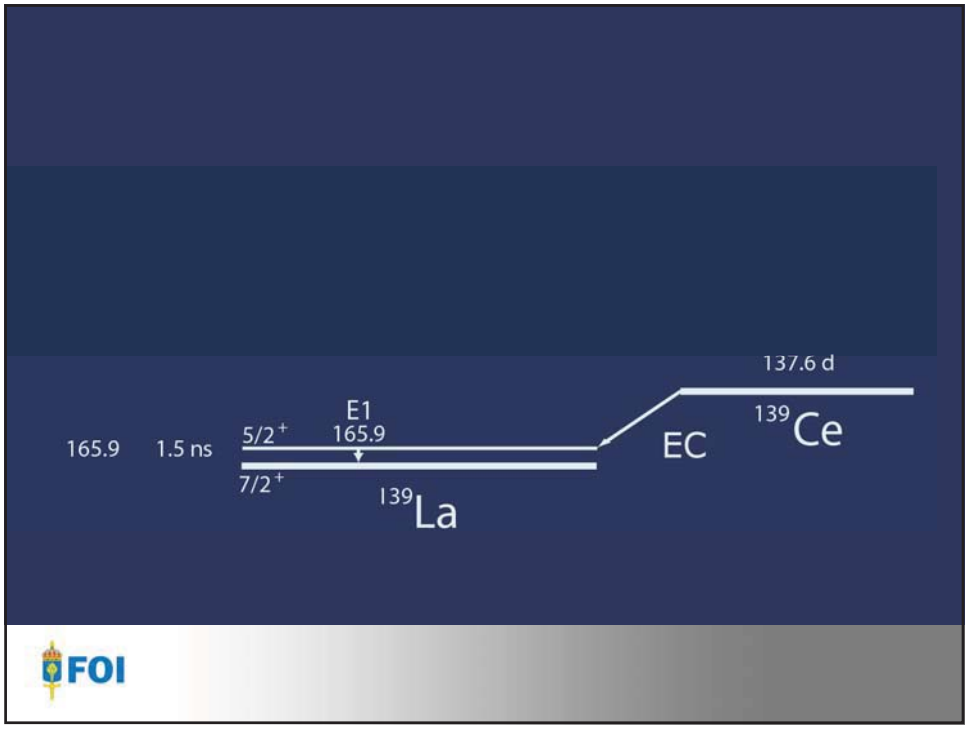
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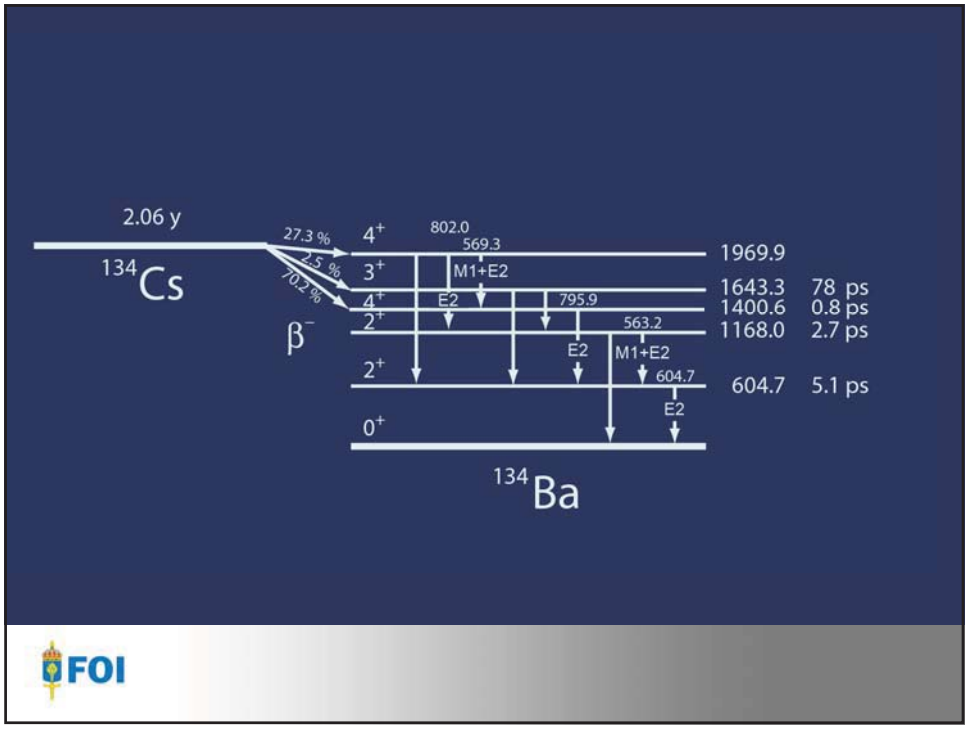
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M1+E2
E2
795.9
563.2
E2
M1+E2
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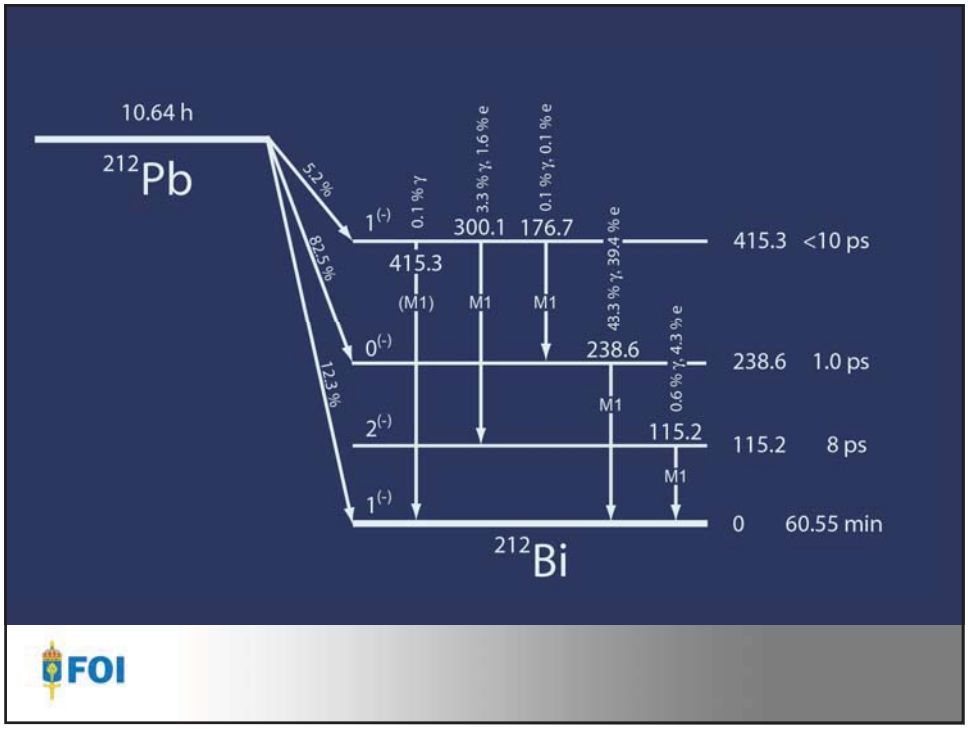
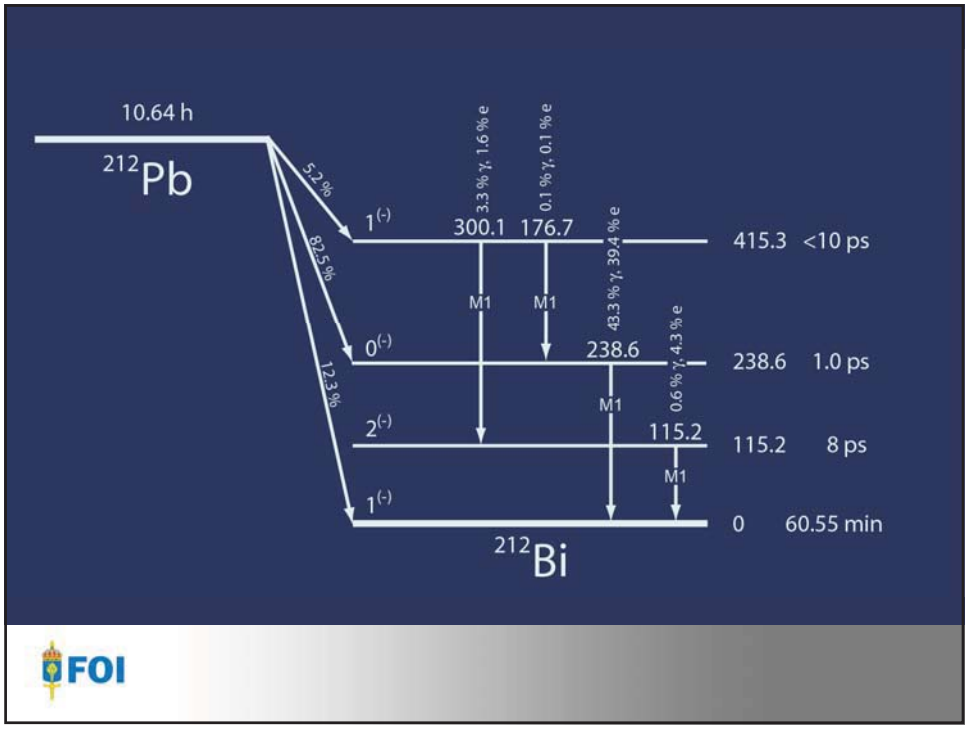
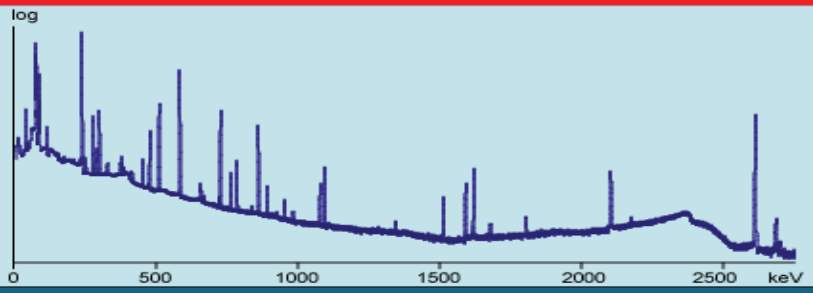
FOI


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

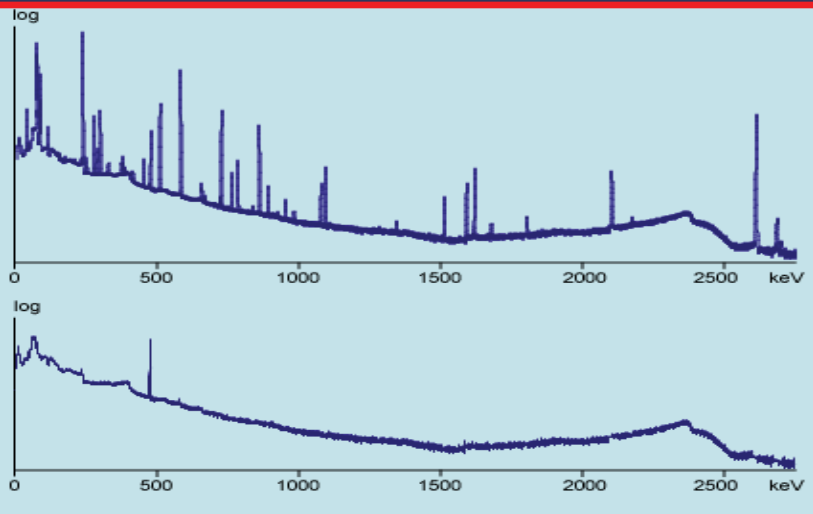

10.64 h
212Pb
5.2 %
82.5 %
12.3 %
1(-)
3.3 % γ, 1.6 % e
0.1 % γ, 0.1 % e
300.1
176.7
415.3 <10 ps
M1
M1
43.3 % γ, 39.4 % e
0(-)
238.6
238.6 1.0 ps
0.6 % γ, 4.3 % e
M1
2(-)
115.2
115.2 8 ps
M1
1(-)
0 60.55 min
212Bi
FOI

The Lead Picker



FOI

The Lead Picker



FOI

Sinnko

Debertin

Aaltonen, Ugletveit

Korsum

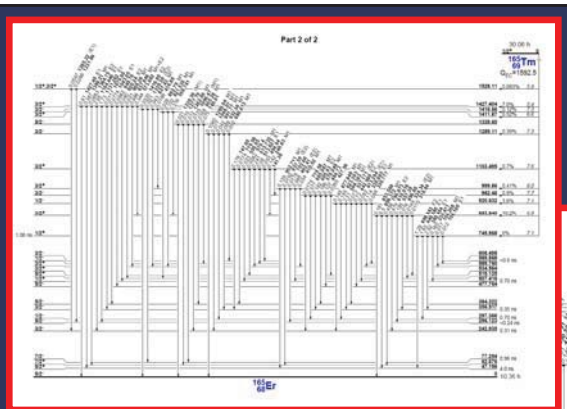
Shaman

GESPECOR

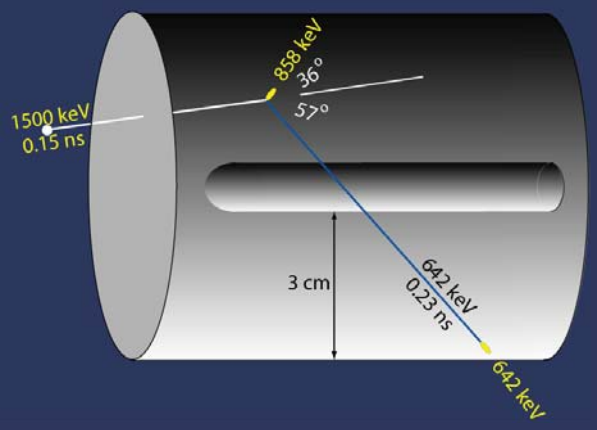
VGSL

ISOCS, LabSOCS

FOI



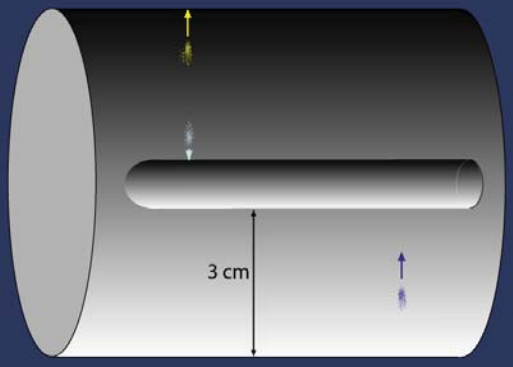
FOI



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

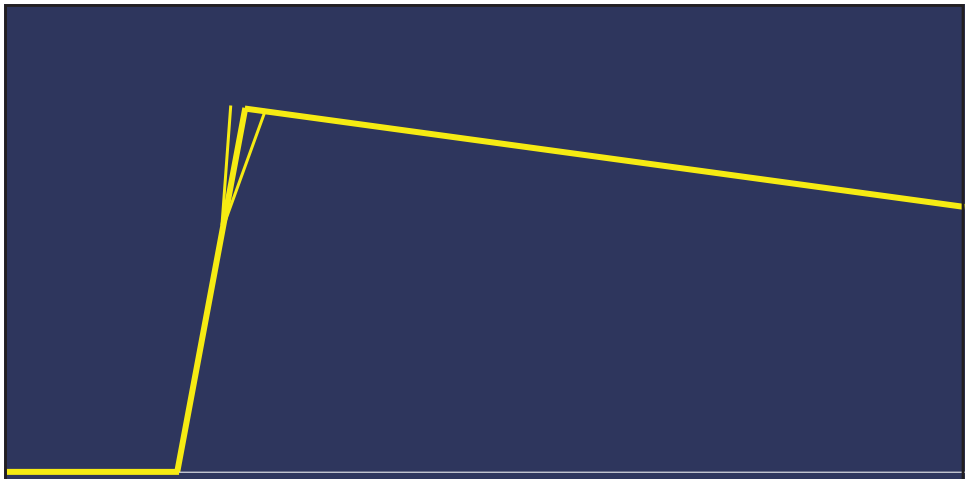
FOI

120 ns later



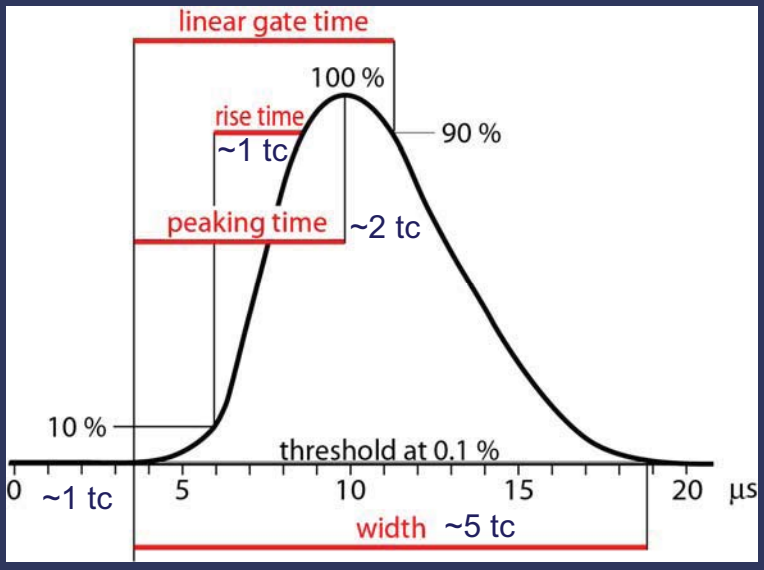
Saturated drifting velocities for both holes and electrons around 7.5 cm per µs imply a preamplifier rise time of about 400 ns. About 300 000 and 200 000 secondary electrons drift towards the mantle and the same number of holes drift towards the center hole [sic].

FOI



400 ns 50 000 – 150 000 ns

FOI



FOI

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

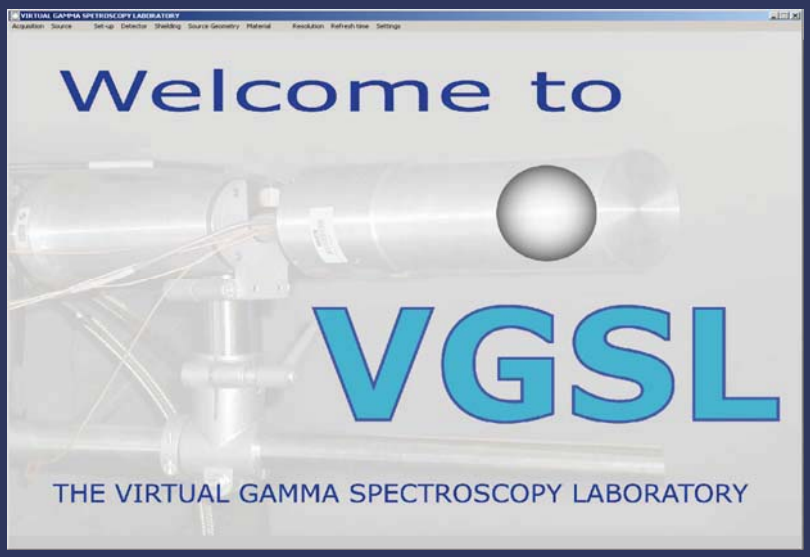
The ADC will deliver the count to the spectrum late tonight

At 10 cps we can expect next event in November 2013

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

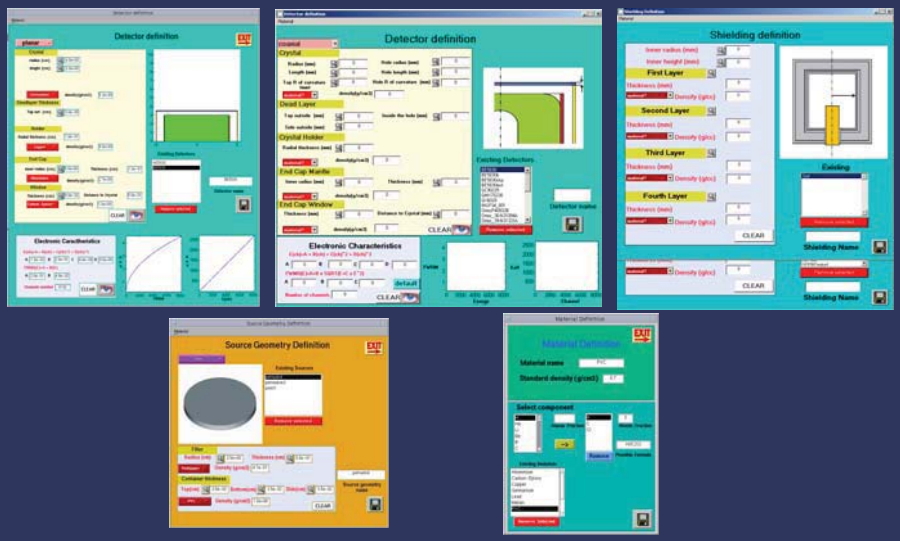
FOI

Time constant tc = 3 µs

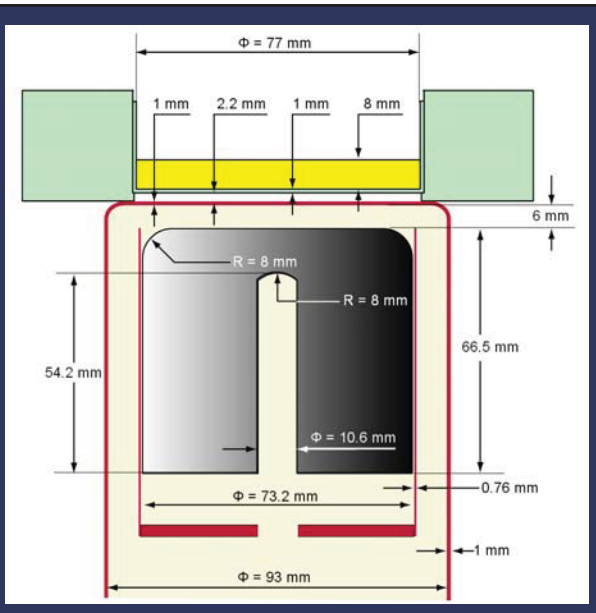


FOI

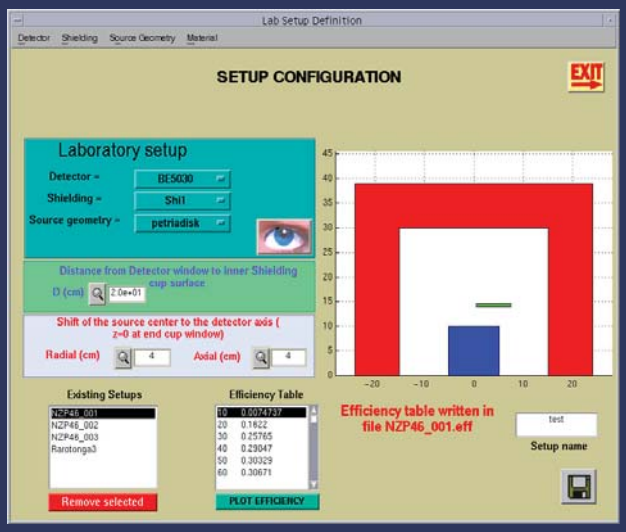
Investing in the laboratory



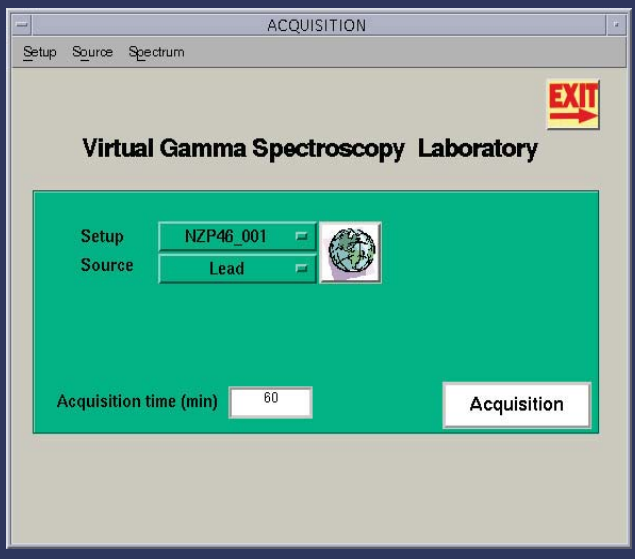
FOI



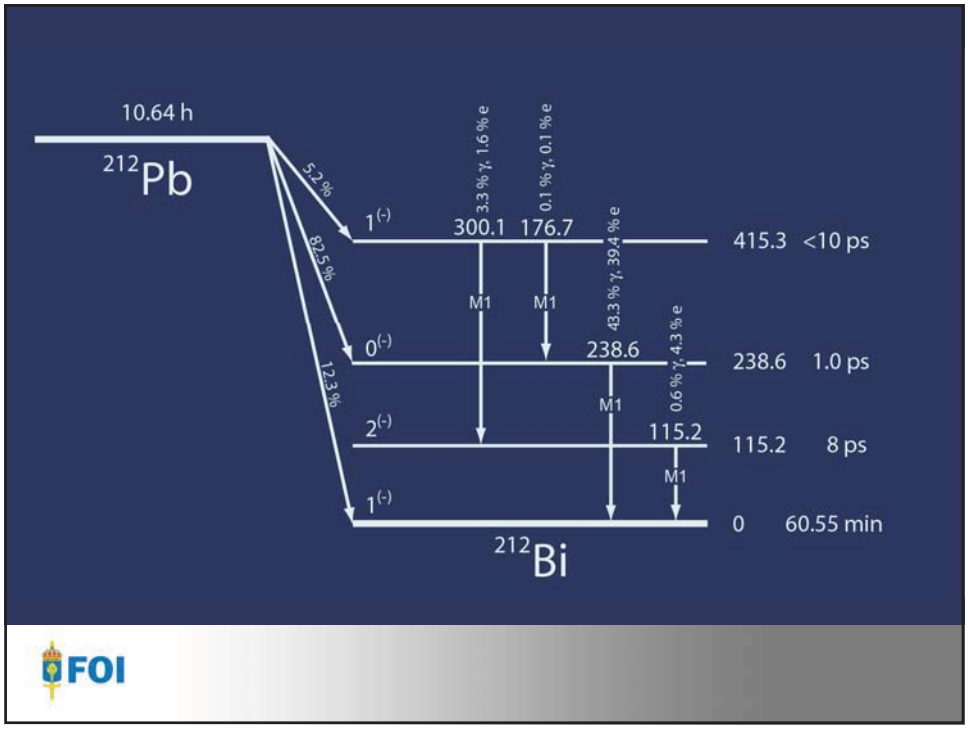
FOI

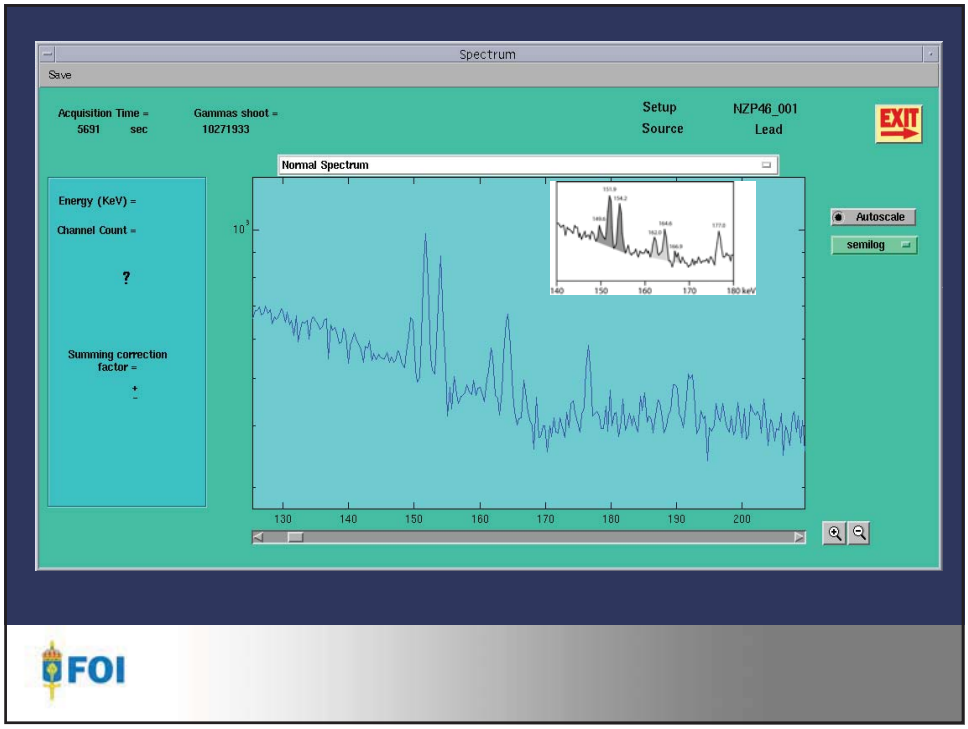

Lab Setup Definition
Detector Shielding Source Geometry Material
SETUP CONFIGURATION
EXIT
Laboratory setup
Detector =
BE5030
Shielding =
Shl1
Source geometry =
petriadisk
Distance from Detector window to Inner Shielding cup surface
D (cm)
2.0e+01
Shift of the source center to the detector axis (z=0 at end cup window)
Radial (cm)
4
Axial (cm)
4
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

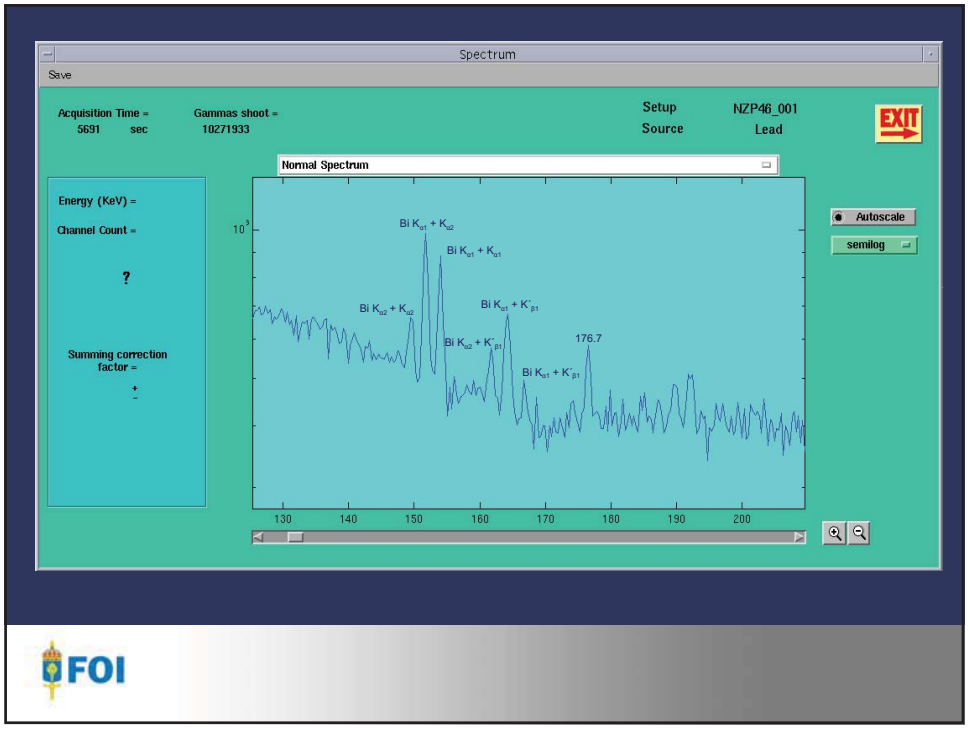
FOI

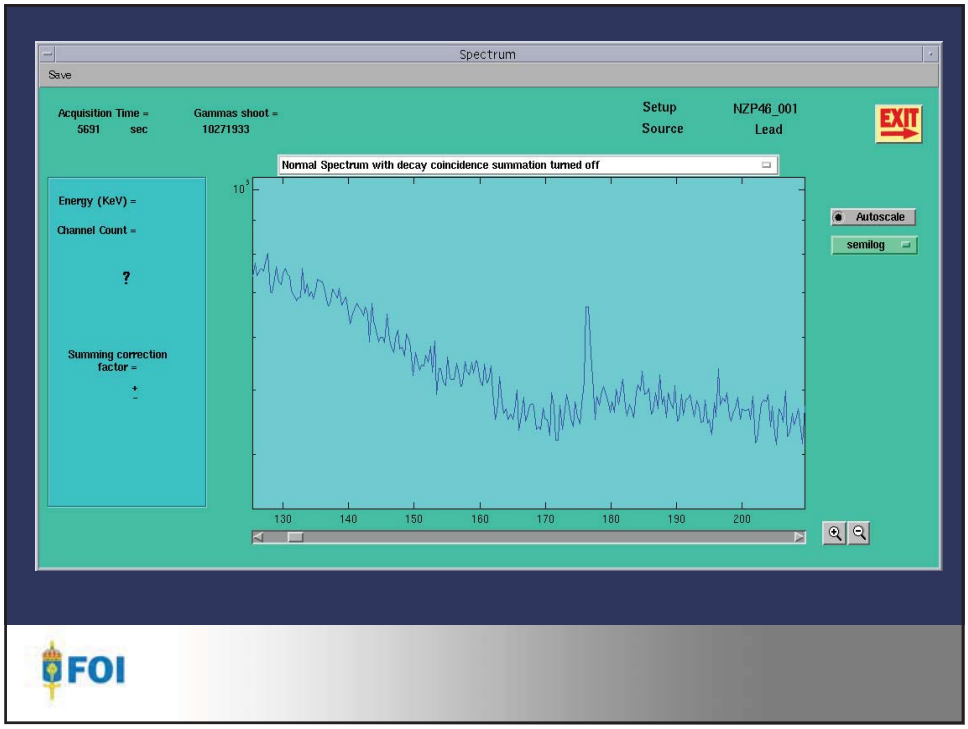

ACQUISITION
Setup Source Spectrum
EXIT
Virtual Gamma Spectroscopy Laboratory
Setup
NZP46_001
Source
Lead
Acquisition time (min)
60
Acquisition

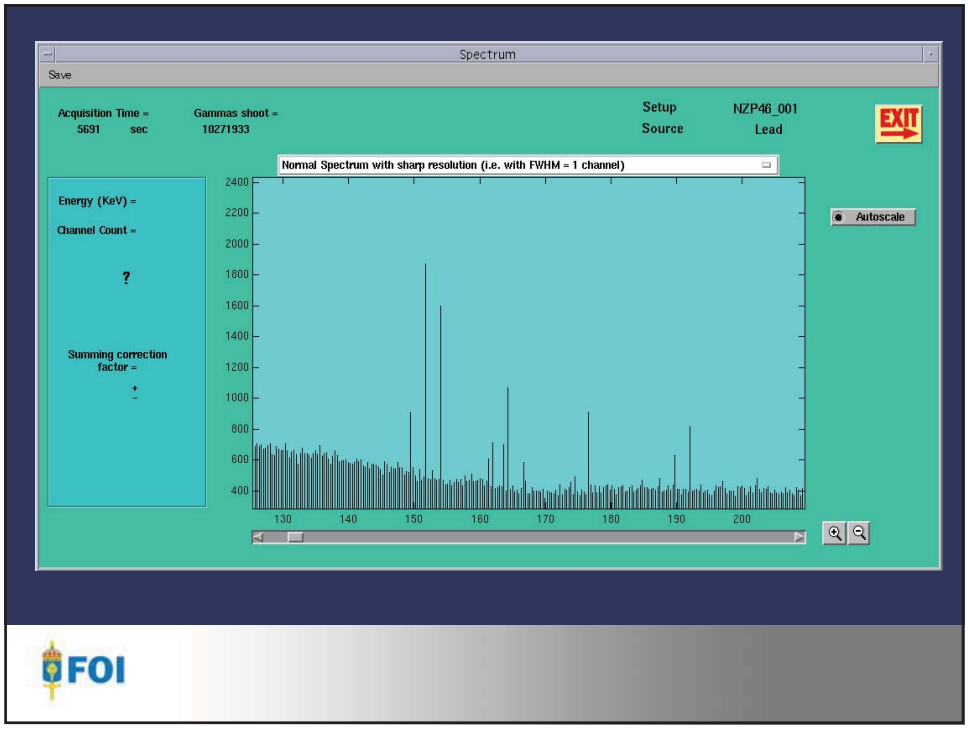
FOI

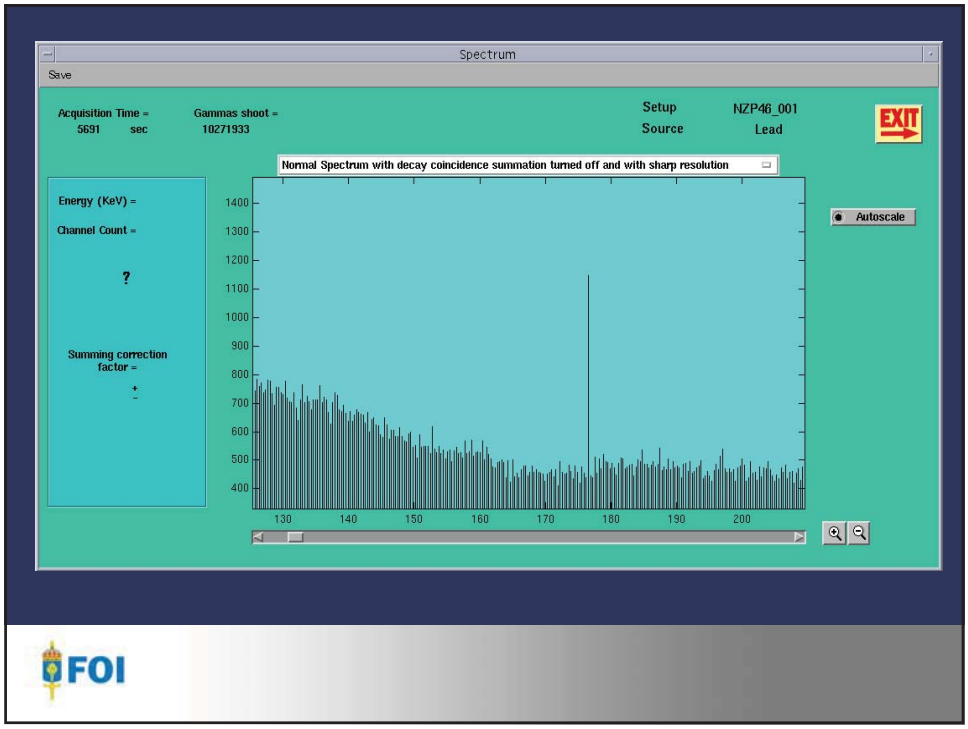

10.64 h
212Pb
5.2 %
82.5 %
12.3 %
1(-)
0(-)
2(-)
1(-)
300.1
176.7
238.6
115.2
3.3 % γ, 1.6 % e
0.1 % γ, 0.1 % e
43.3 % γ, 39.4 % e
0.6 % γ, 4.3 % e
M1
M1
M1
M1
415.3 <10 ps
238.6 1.0 ps
115.2 8 ps
0 60.55 min
212Bi
FOI

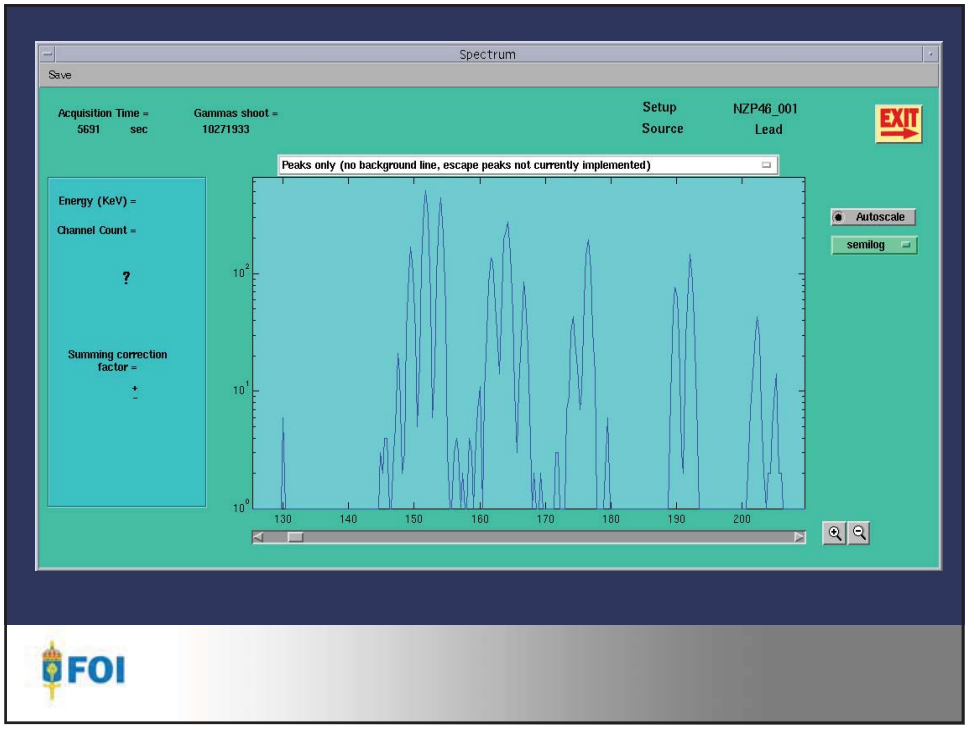

Spectrum
Save
Acquisition Time =
5691 sec
Gammas shoot =
10271933
Setup
Source
NZP46_001
Lead
EXIT
Normal Spectrum
Energy (KeV) =
Channel Count =
?
Summing correction factor =
Autoscale
semilog
130
140
150
160
170
180
190
200
FOI

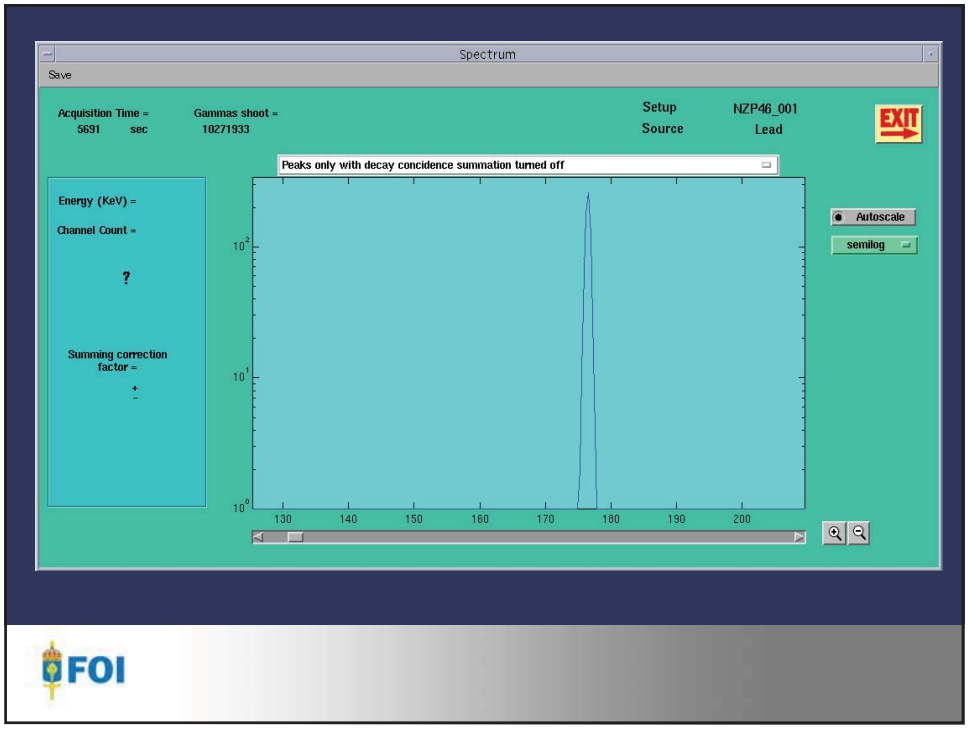

Spectrum
Save
Acquisition Time =
5691 sec
Gammas shoot =
10271933
Setup
NZP46_001
Source
Lead
EXIT
Normal Spectrum
Energy (KeV) =
Channel Count =
?
Summing correction factor =
Autoscale
semilog
Bi Kα1 + Kα2
Bi Kα1 + Kα1
Bi Kα2 + Kα2
Bi Kα1 + K'β1
Bi Kα2 + K'β1
176.7
Bi Kα1 + K'β1
130 140 150 160 170 180 190 200

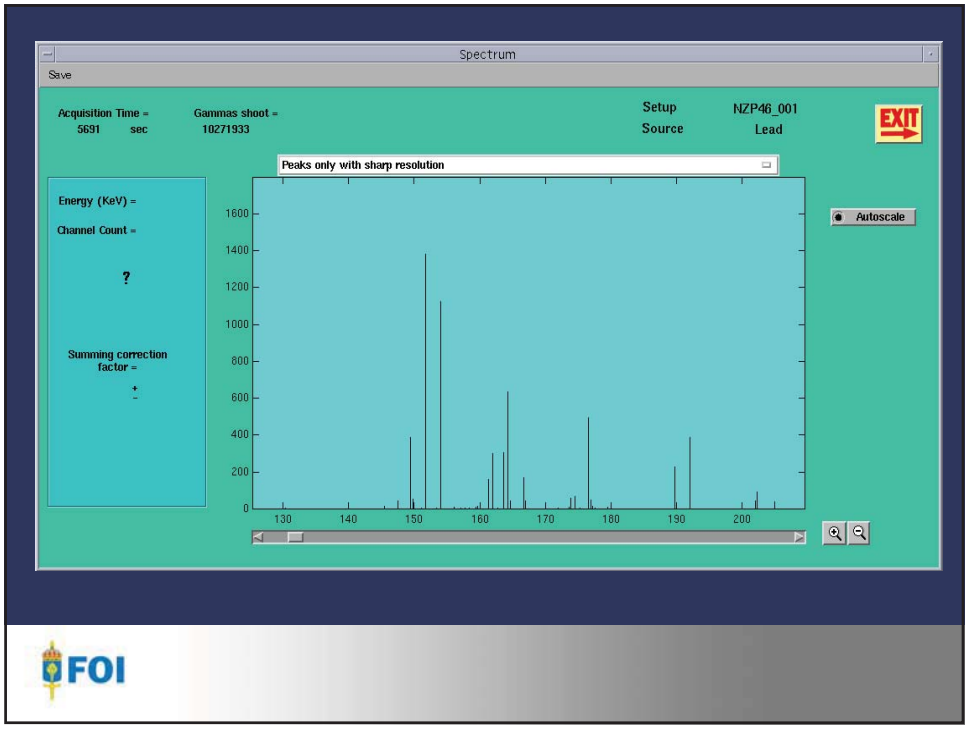

Spectrum
Save
Acquisition Time =
5691 sec
Gammas shoot =
10271933
Setup
NZP46_001
Source
Lead
EXIT
Normal Spectrum with decay coincidence summation turned off
Energy (KeV) =
Channel Count =
?
Summing correction factor =
Autoscale
semilog
130 140 150 160 170 180 190 200


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 =
Autoscale
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
130
140
150
160
170
180
190
200
FOI

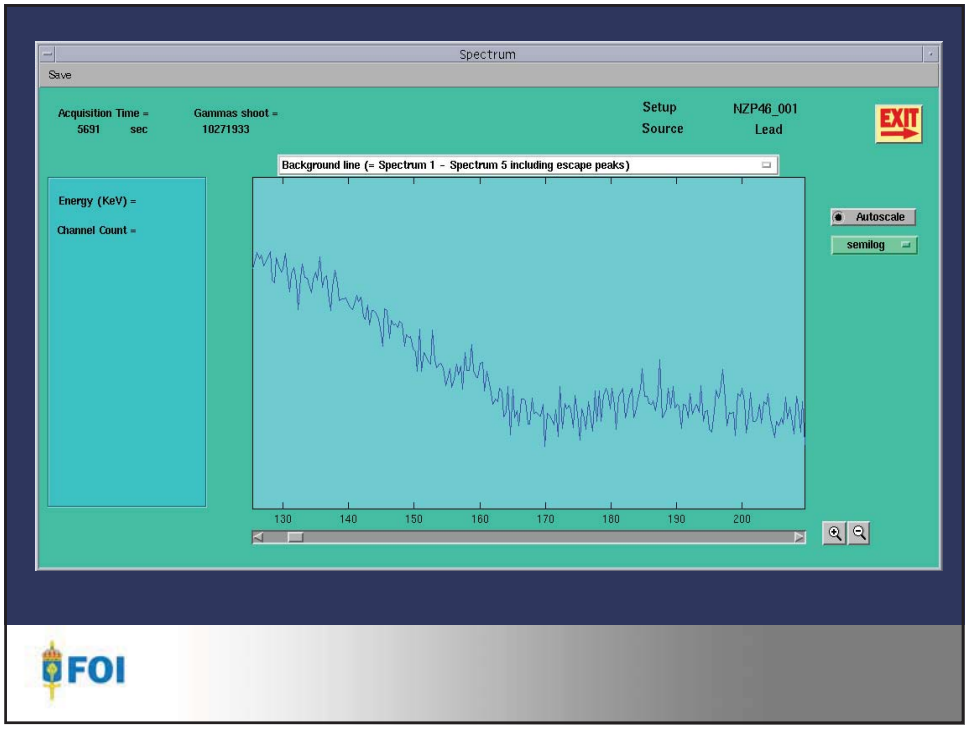

Spectrum
Save
Acquisition Time =
5691 sec
Gammas shoot =
10271933
Setup
NZP46_001
Source
Lead
EXIT
Normal Spectrum with decay coincidence summation turned off and with sharp resolution
Energy (KeV) =
Channel Count =
?
Summing correction factor =
Autoscale
1400
1300
1200
1100
1000
900
800
700
600
500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

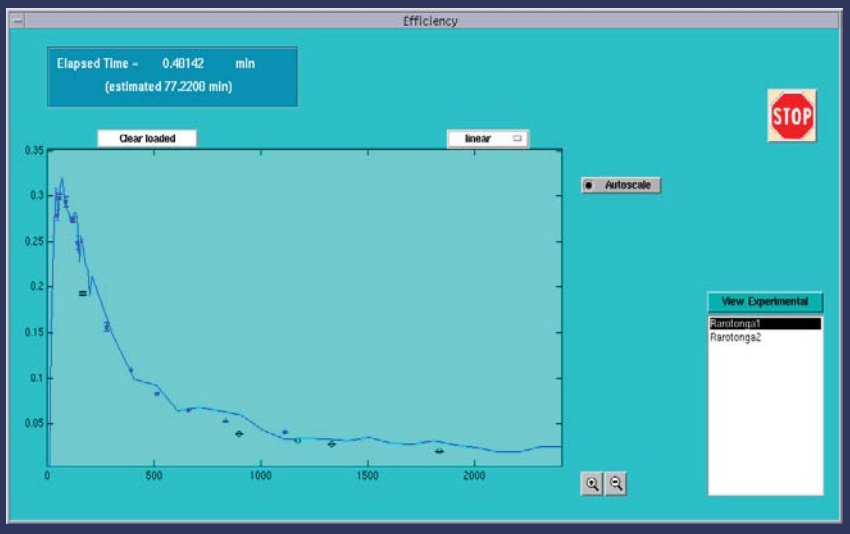

Spectrum
Save
Acquisition Time =
5691 sec
Gammas shoot =
10271933
Setup
NZP46_001
Source
Lead
EXIT
Peaks only with sharp resolution
Energy (KeV) =
Channel Count =
?
Summing correction factor =
Autoscale
1600
1400
1200
1000
800
600
400
200
0
130
140
150
160
170
180
190
200
FOI


Spectrum
Save
Acquisition Time =
5691 sec
Gammas shoot =
10271933
Setup
NZP46_001
Source
Lead
EXIT
Peaks only with decay coincidence summation turned off and with sharp resolution
Energy (KeV) =
Channel Count =
?
Summing correction factor =
Autoscale
800
700
600
500
400
300
200
100
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
Background line (= Spectrum 1 - Spectrum 5 including escape peaks)
Energy (KeV) =
Channel Count =
Autoscale
semilog
130
140
150
160
170
180
190
200
FOI

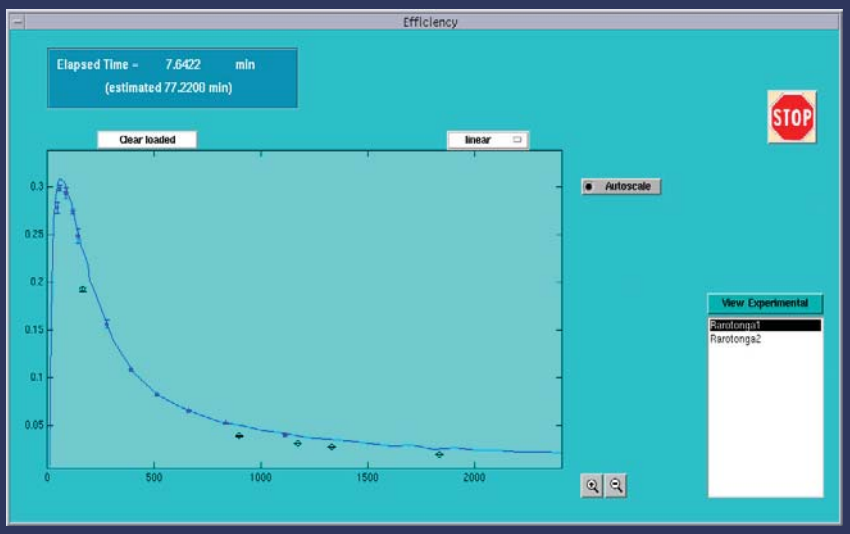

Spectrum
Save
Acquisition Time =
5691 sec
Gammas shoot =
10271933
Setup
NZP46_001
Source
Lead
EXIT
Coincidence Correction Factor (Spectrum 8 diveded by Spectrum 7)
Energy (KeV) =
Summing correction factor =
Autoscale
2.5
2
1.5
1
0.5
0
500
1000
1500
2000
2500
FOI

Efficiency curve after half a minute



FOI

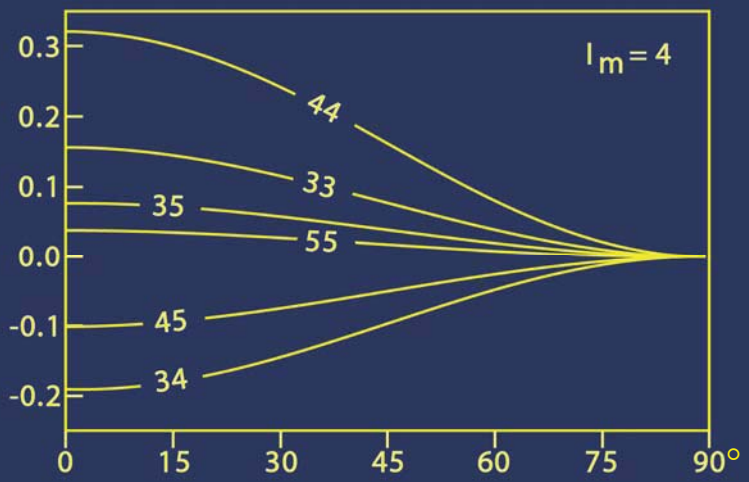
Efficiency curve after 7.6 minutes



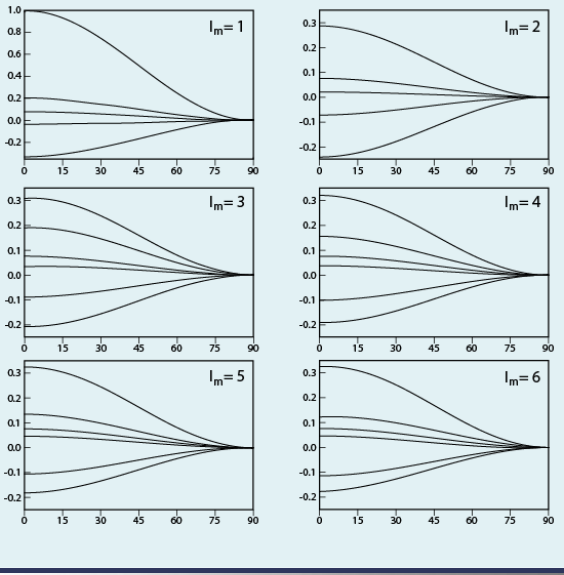
FOI

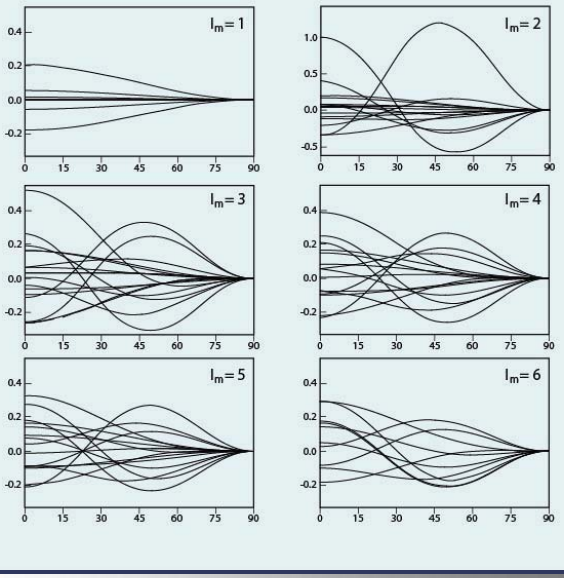
Running an experiment

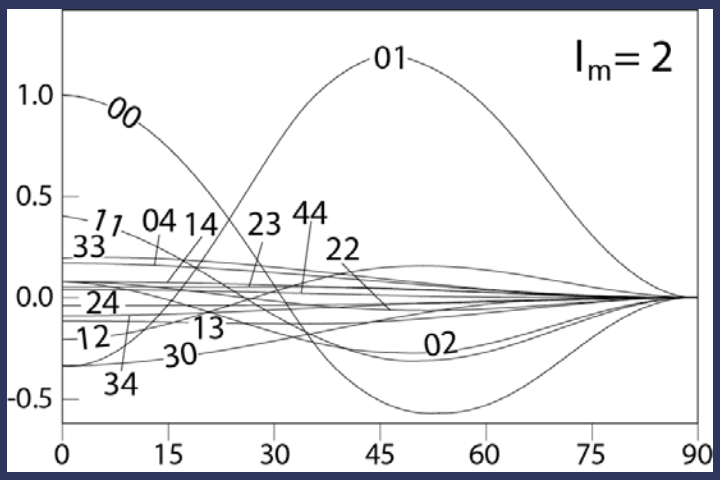
FOI



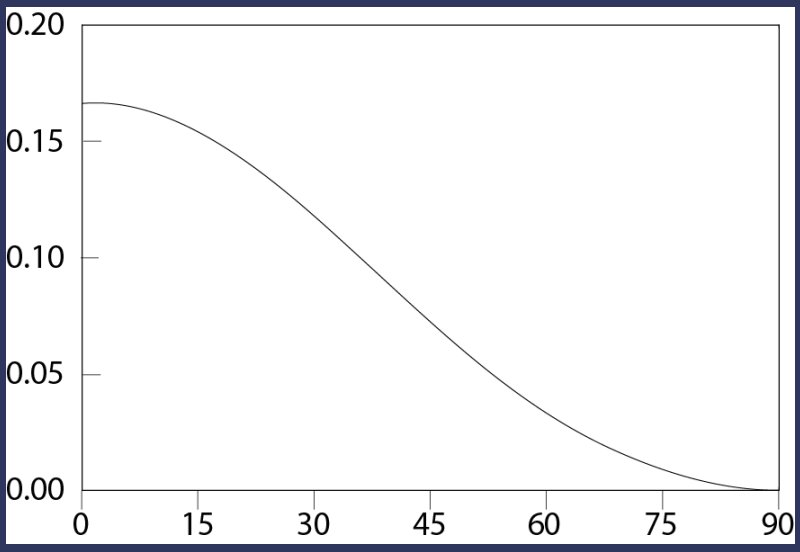
FOI


$l_m = 1$
$l_m = 2$
$l_m = 3$
$l_m = 4$
$l_m = 5$
$l_m = 6$


$l_m = 1$
$l_m = 2$
$l_m = 3$
$l_m = 4$
$l_m = 5$
$l_m = 6$


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

FOI

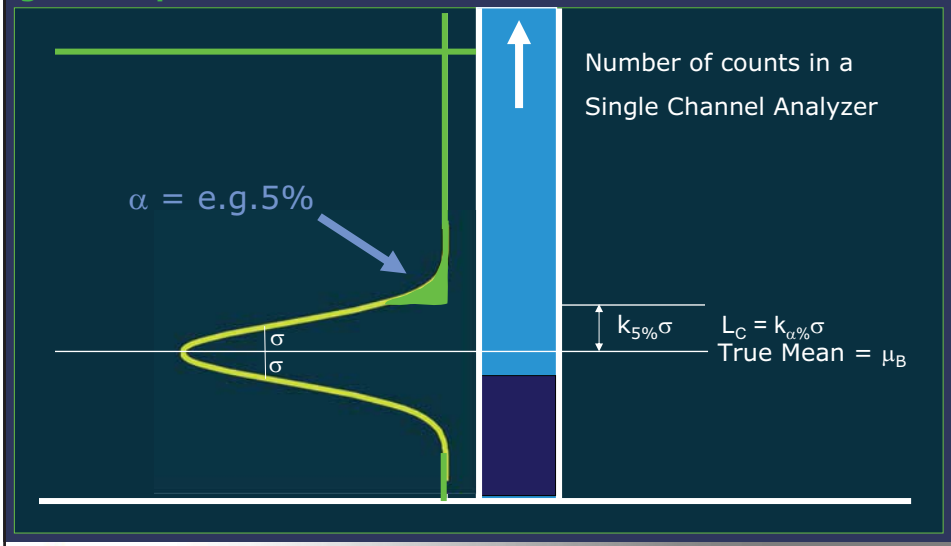

0.20
0.15
0.10
0.05
0.00
0
15
30
45
60
75
90

FOI

A Decent Currie

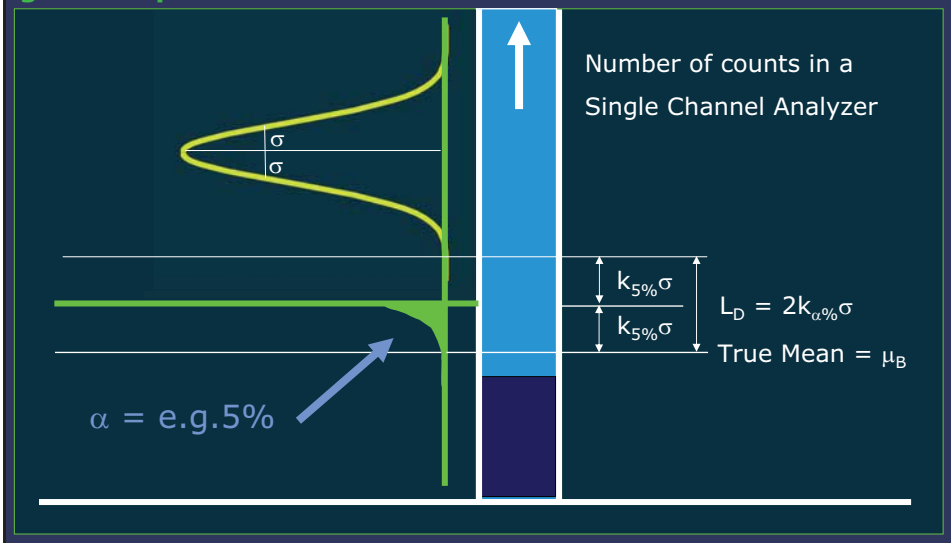
FOI

Applying the Currie SCA to gamma spectra



FOI

Applying the Currie SCA to gamma spectra



FOI

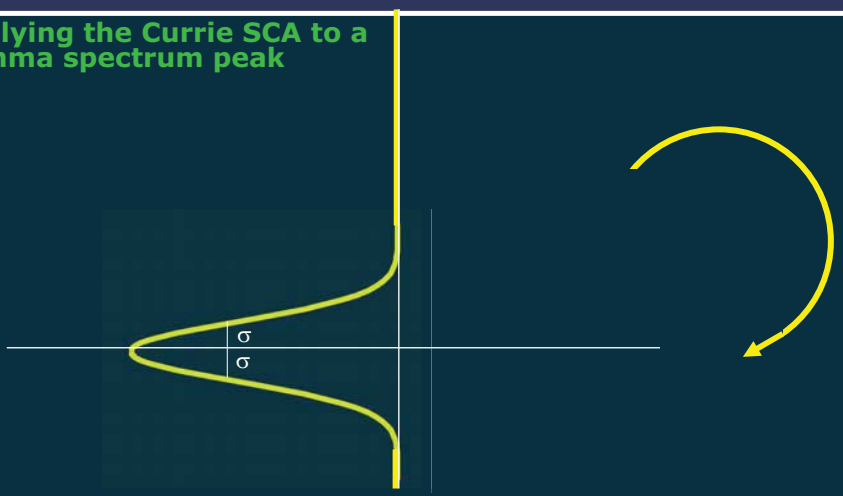
Lloyd Currie's classical paper from 1968

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

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

FOI

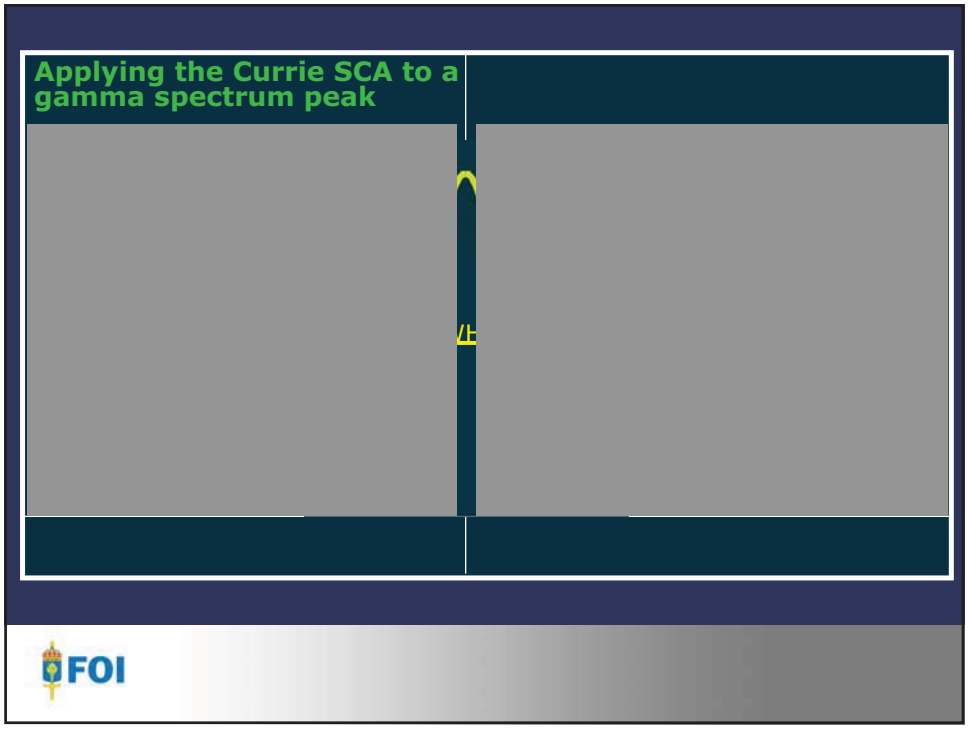
Applying the Currie SCA to a gamma spectrum peak

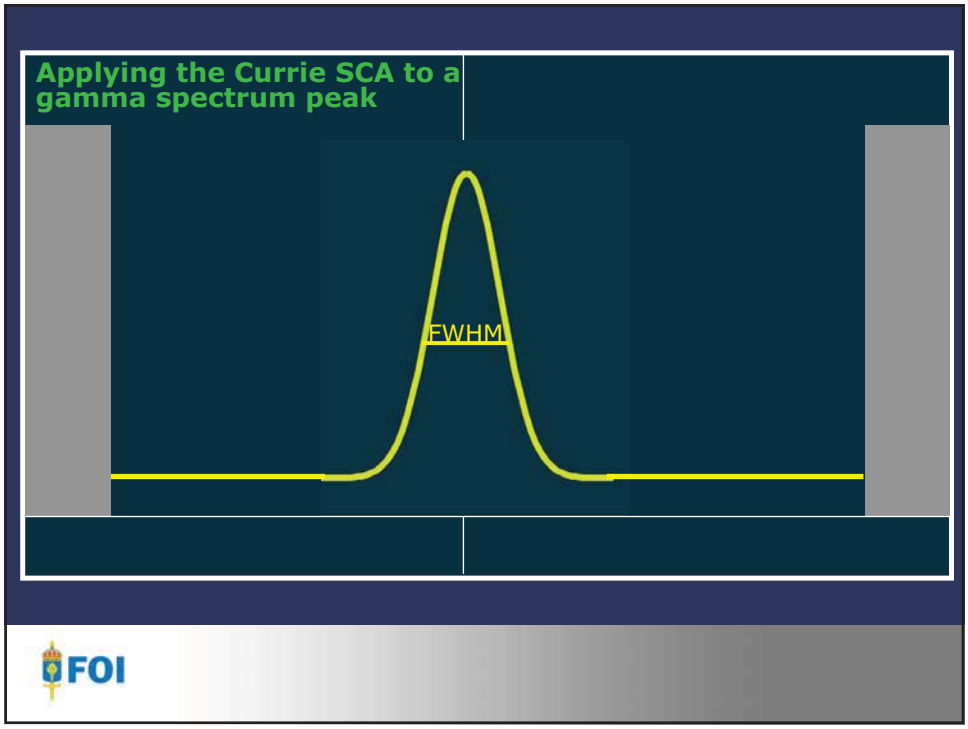


FOI

Applying the Currie SCA to a gamma spectrum peak

FOI

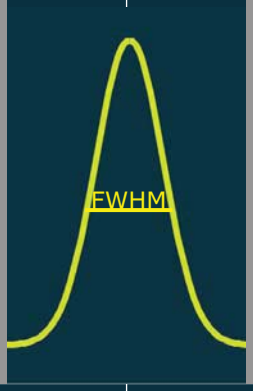

Applying the Currie SCA to a gamma spectrum peak
FOI


Applying the Currie SCA to a gamma spectrum peak
FWHM
FOI

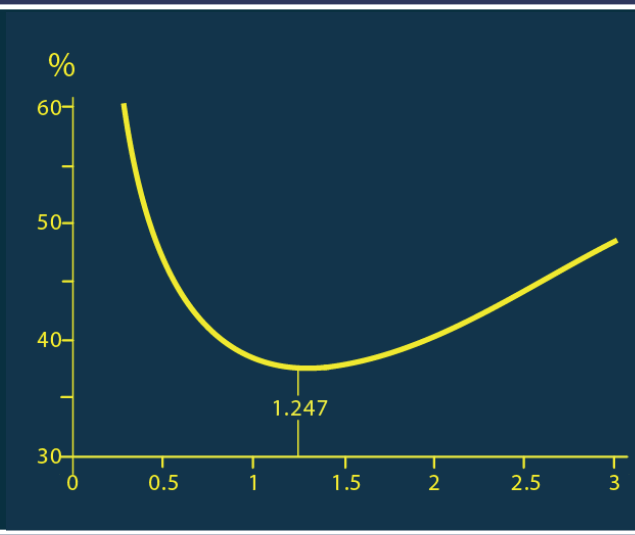
Applying the Currie SCA to a gamma spectrum peak

Commonly used width:

2.5 FWHM



FOI



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 considered 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 $L_D = 2L_C$

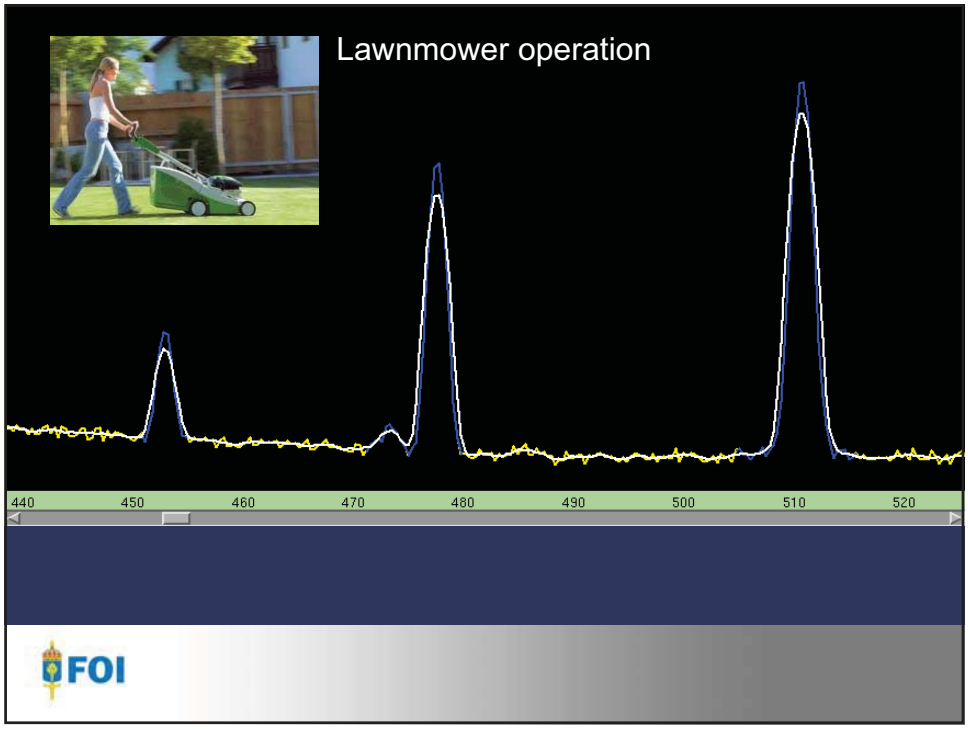
This is much more consistent with experience, as we normally see just around five false positives in a 8192 channel spectrum and not hundreds of them which we would if the risk was really 5%.

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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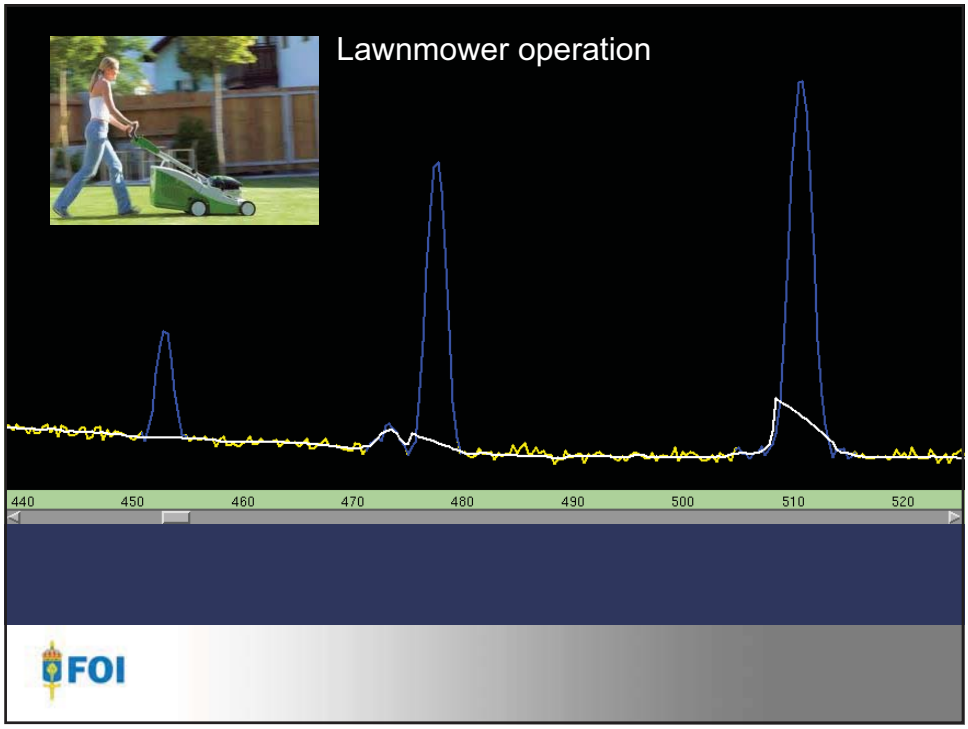
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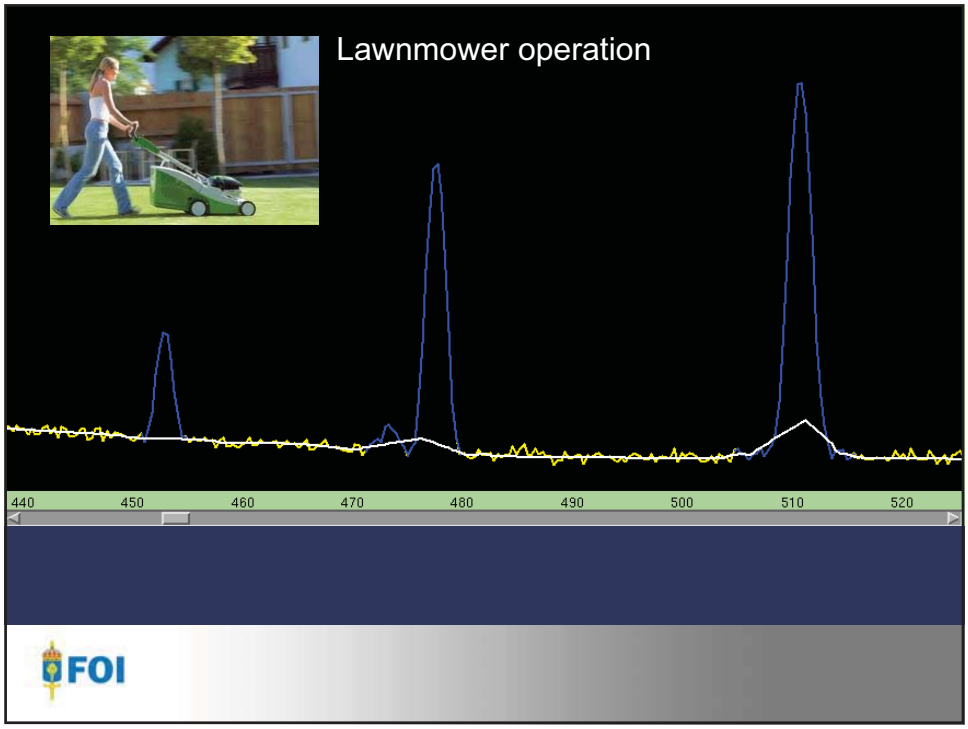
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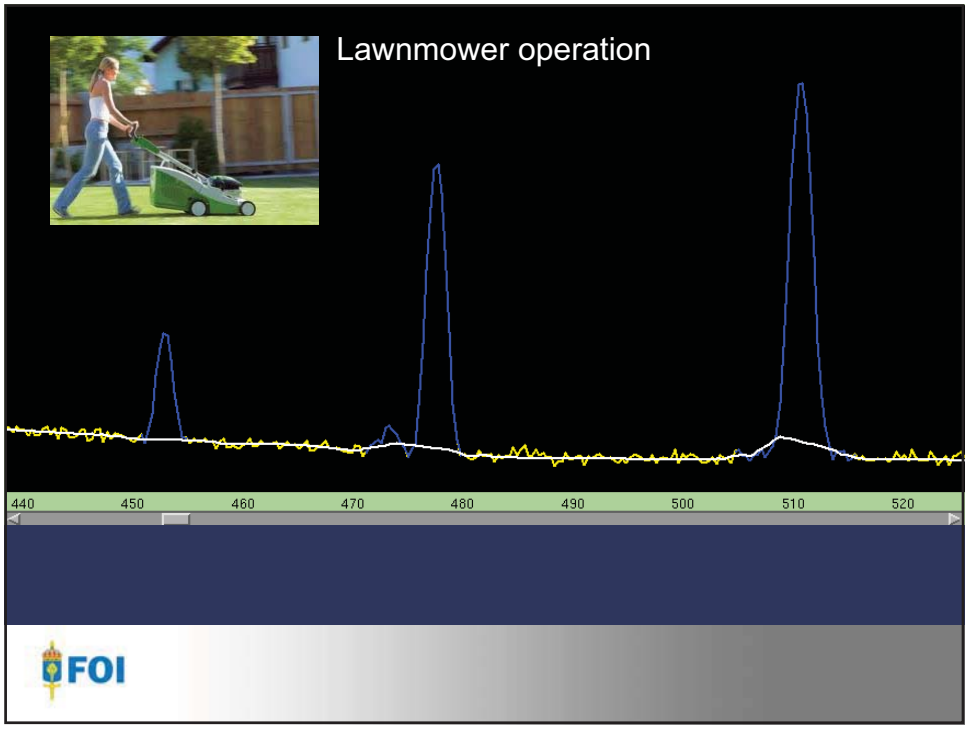
Lawnmower operation
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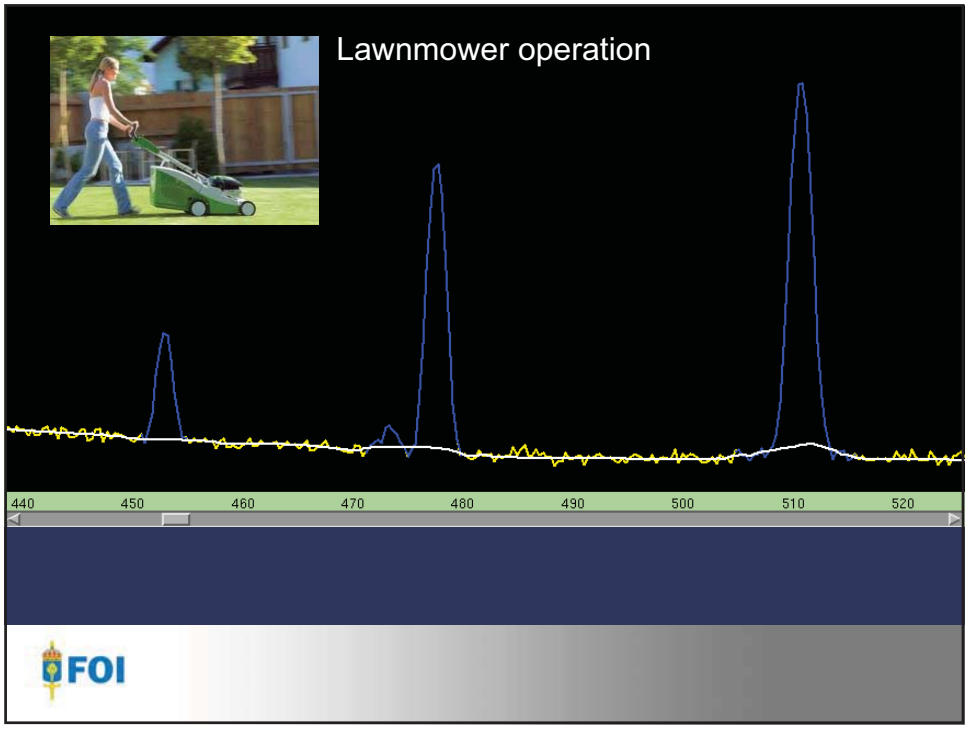
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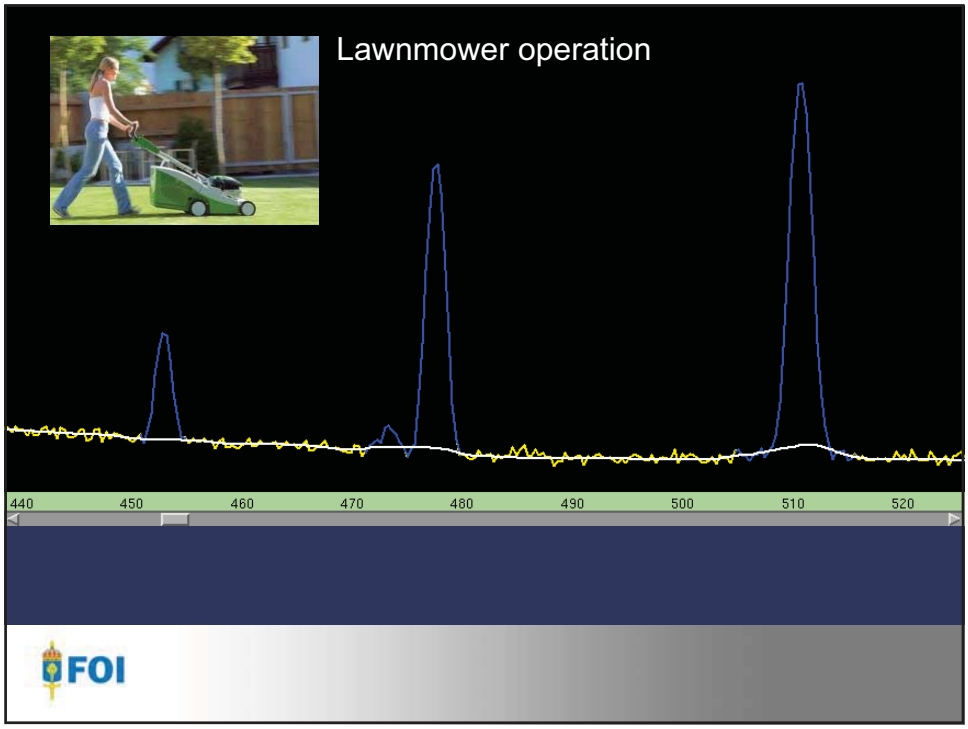
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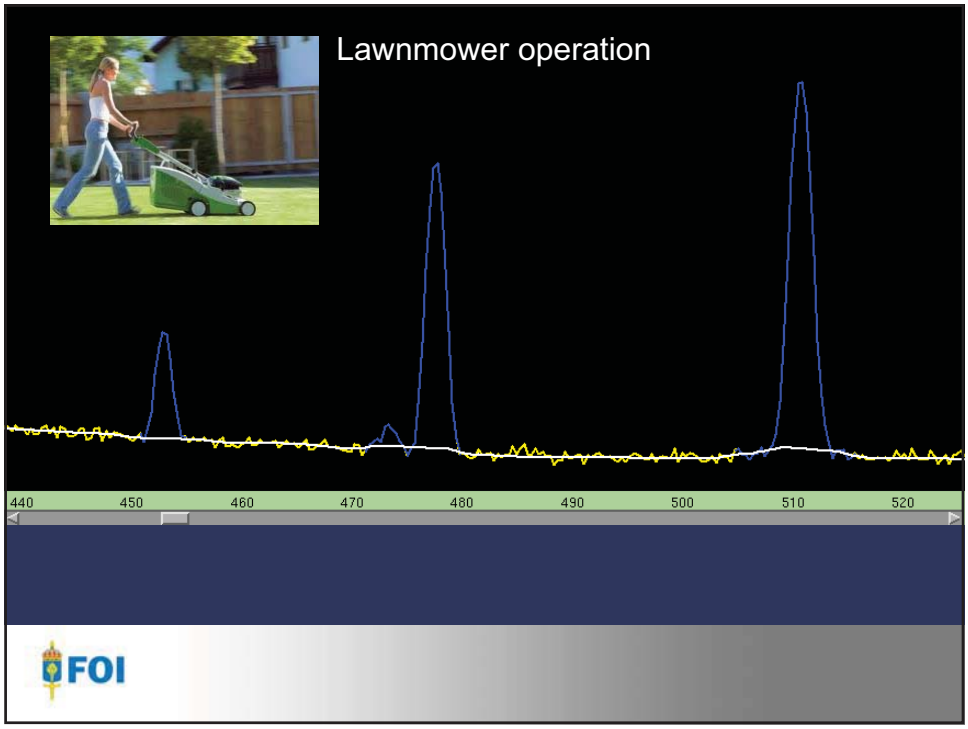
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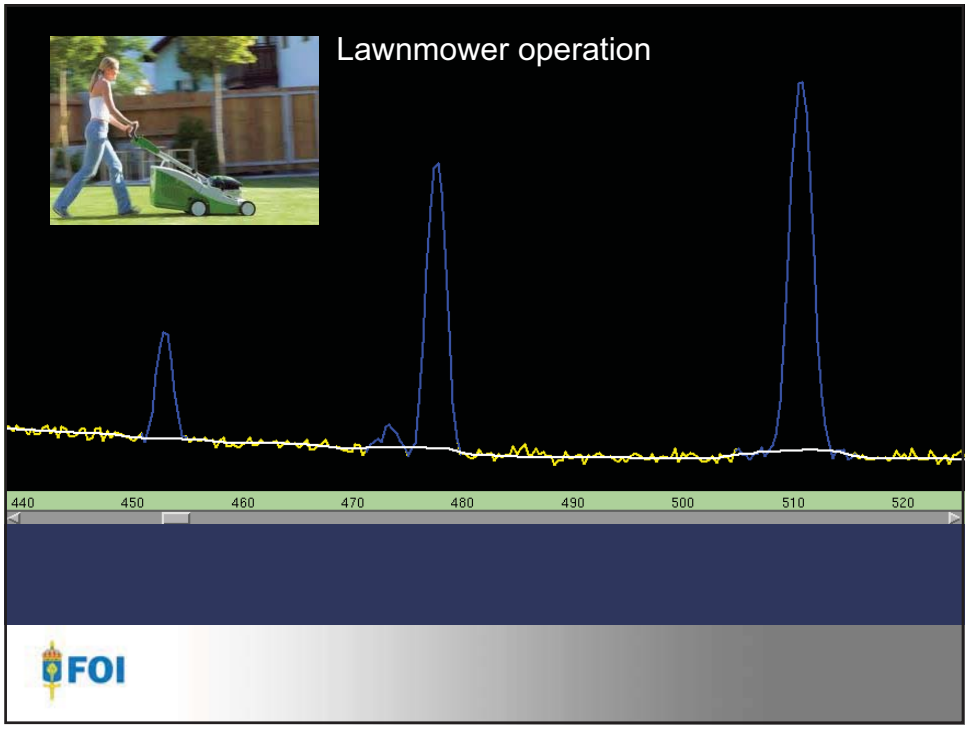
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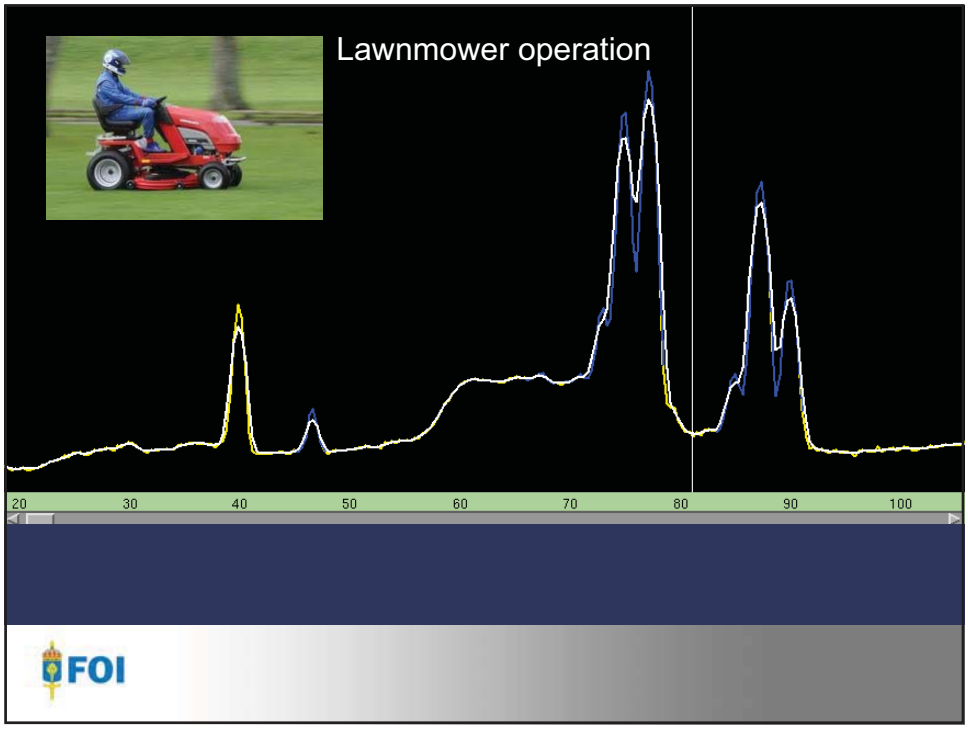
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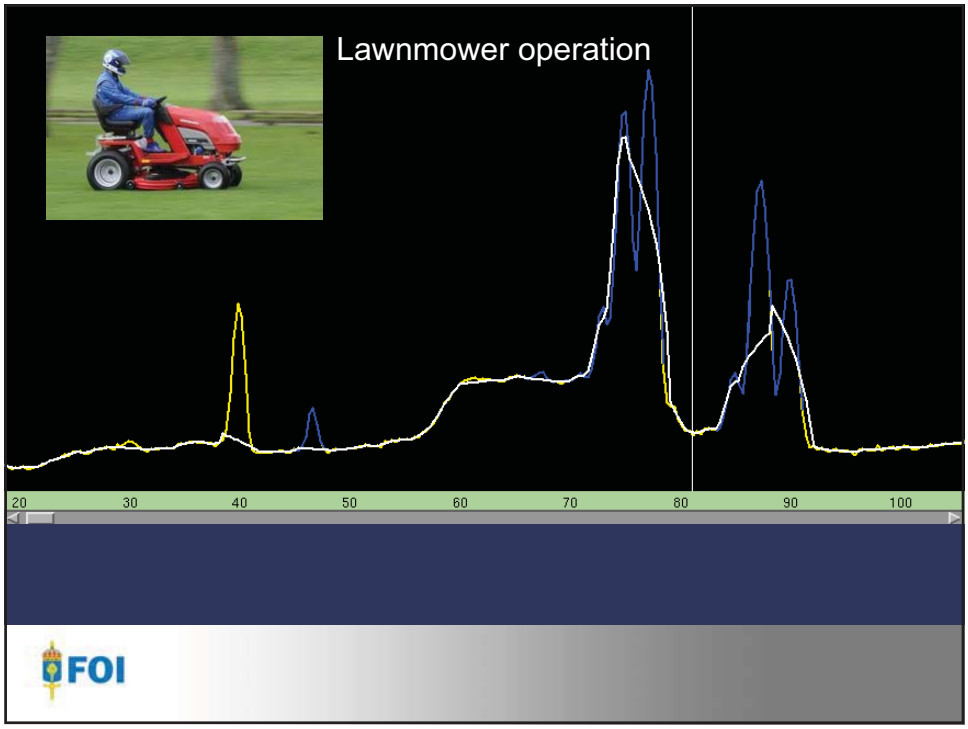
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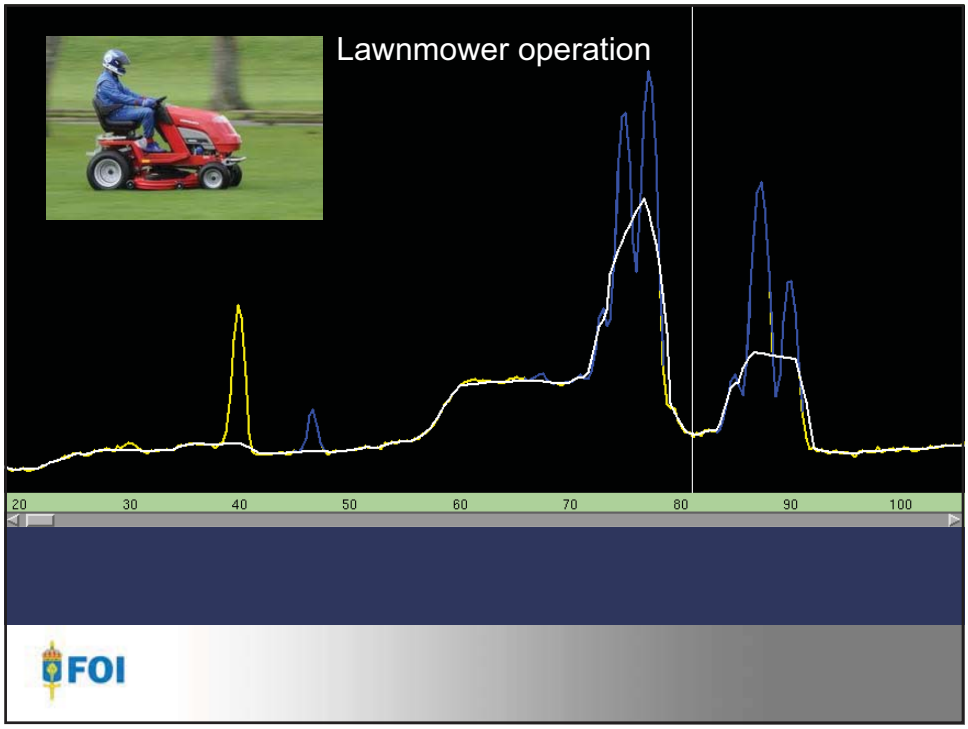
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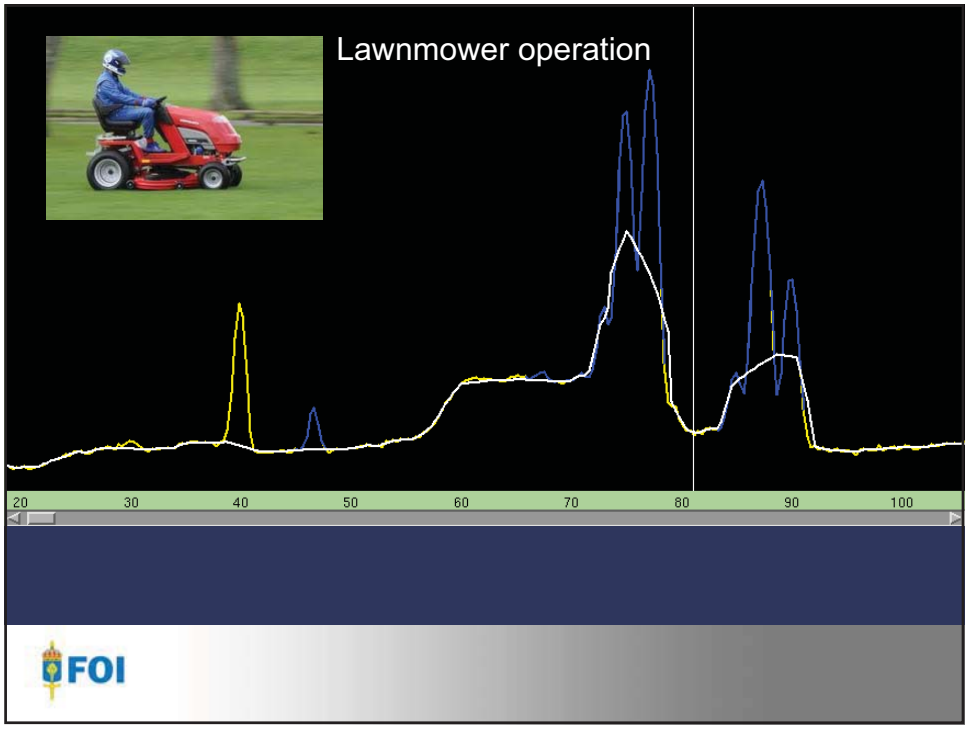
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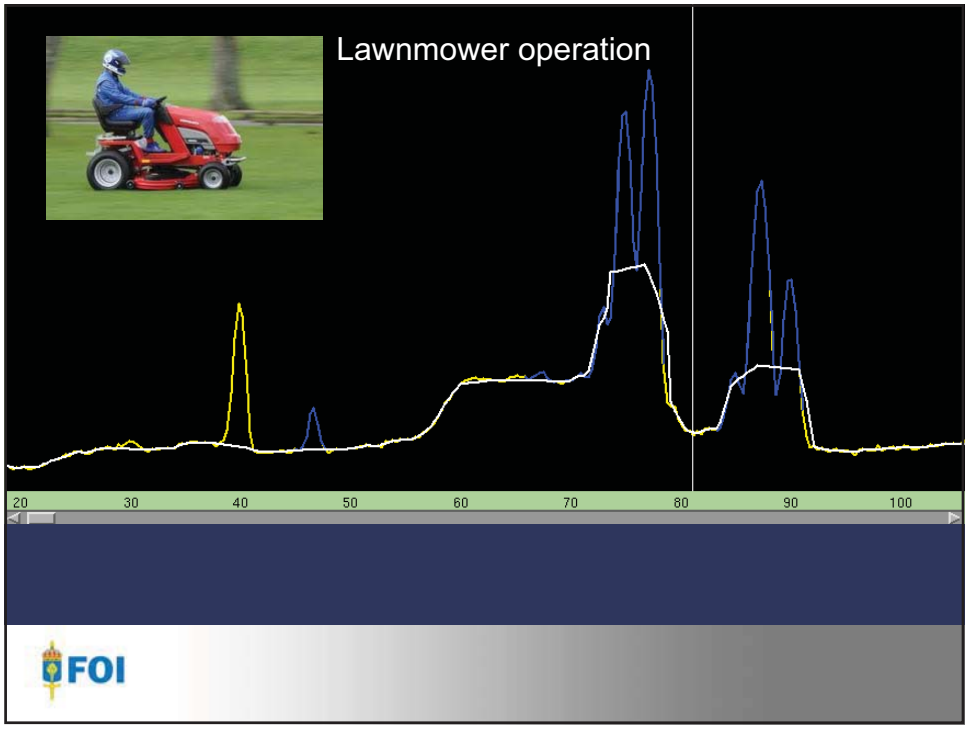
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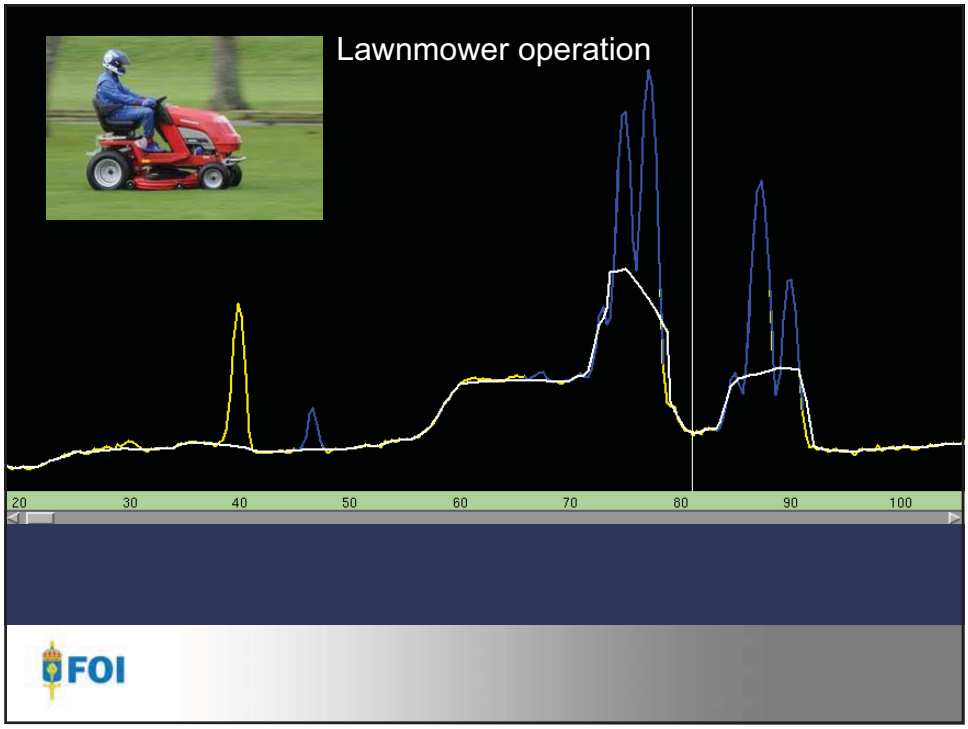
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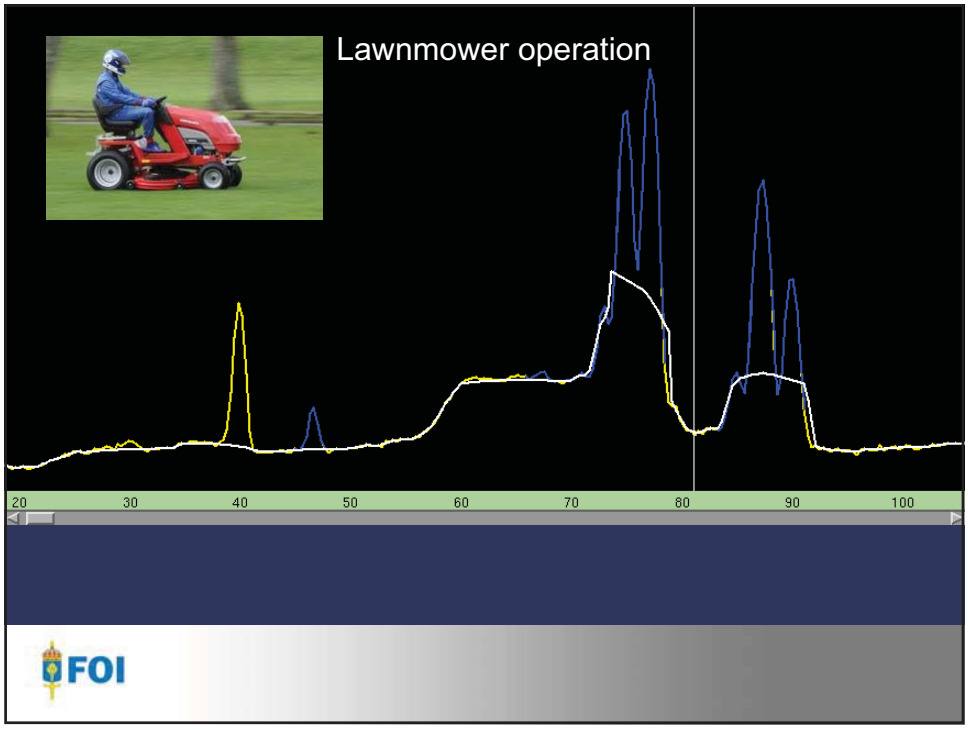
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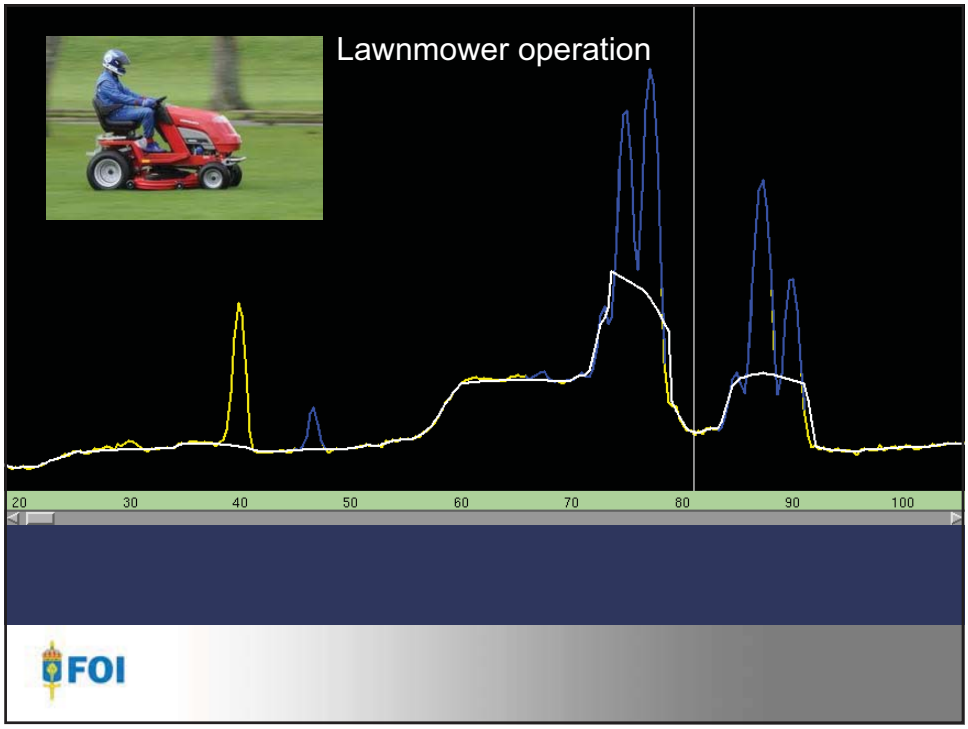
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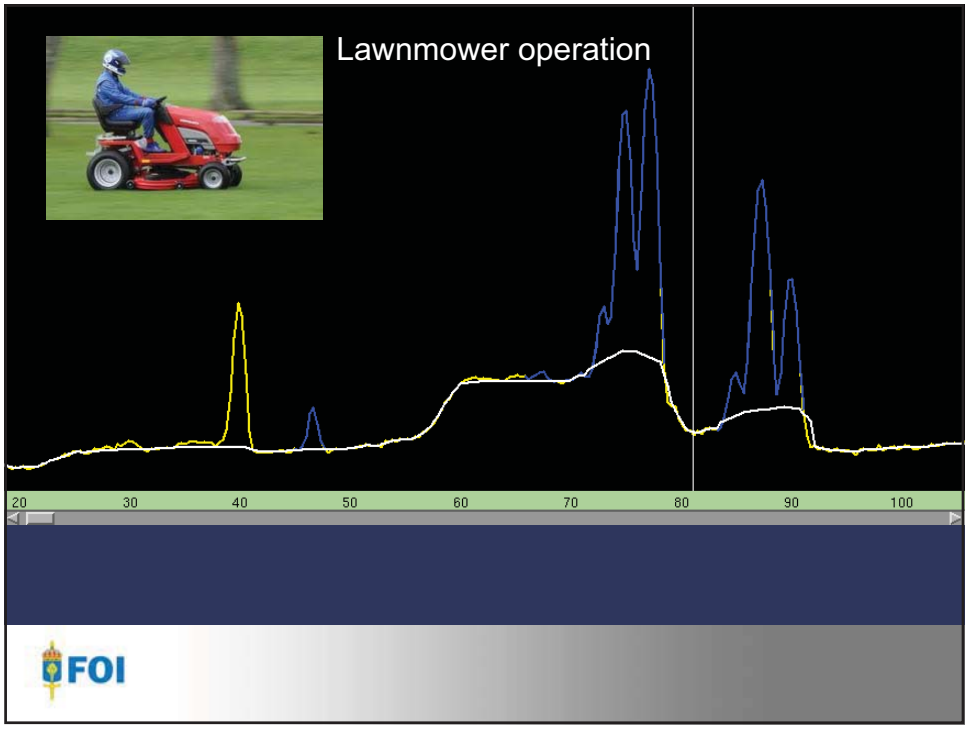
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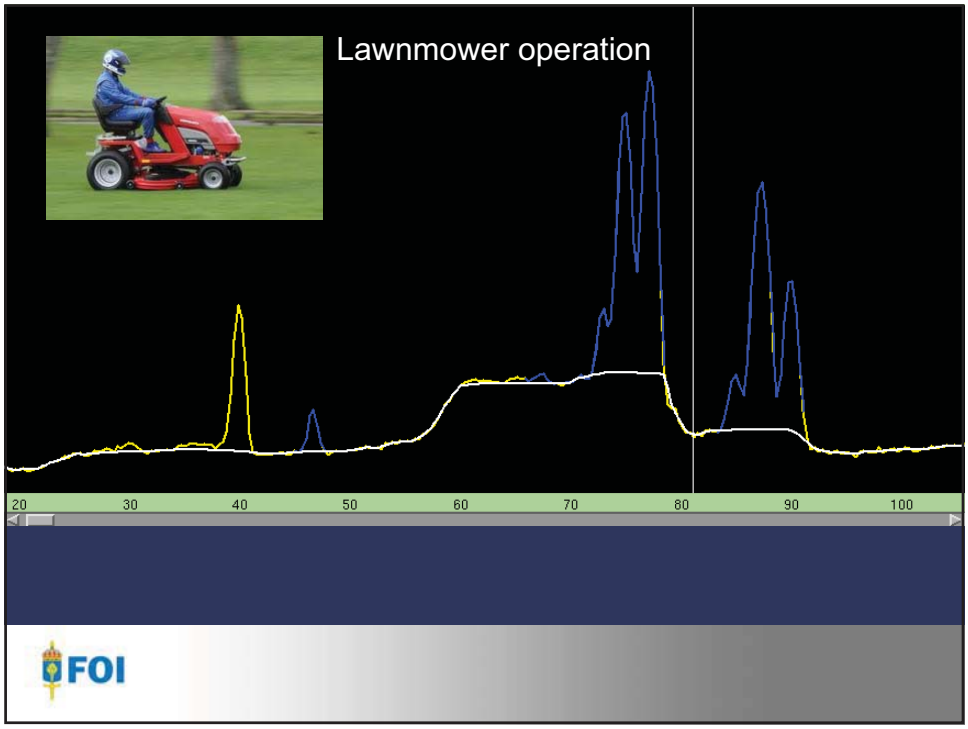
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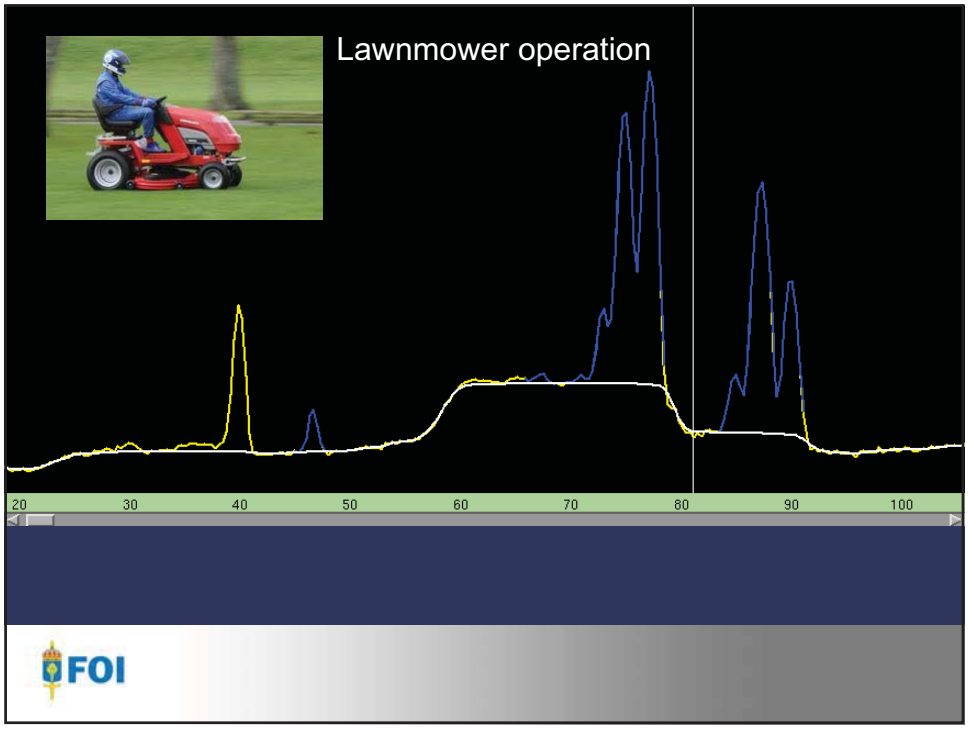
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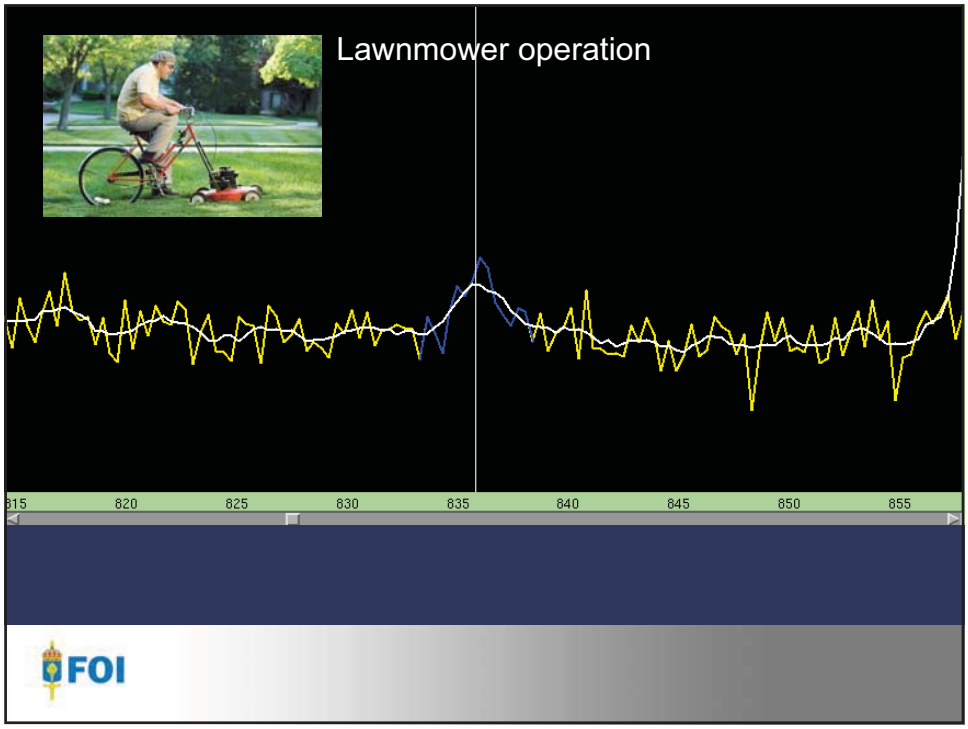
Lawnmower operation
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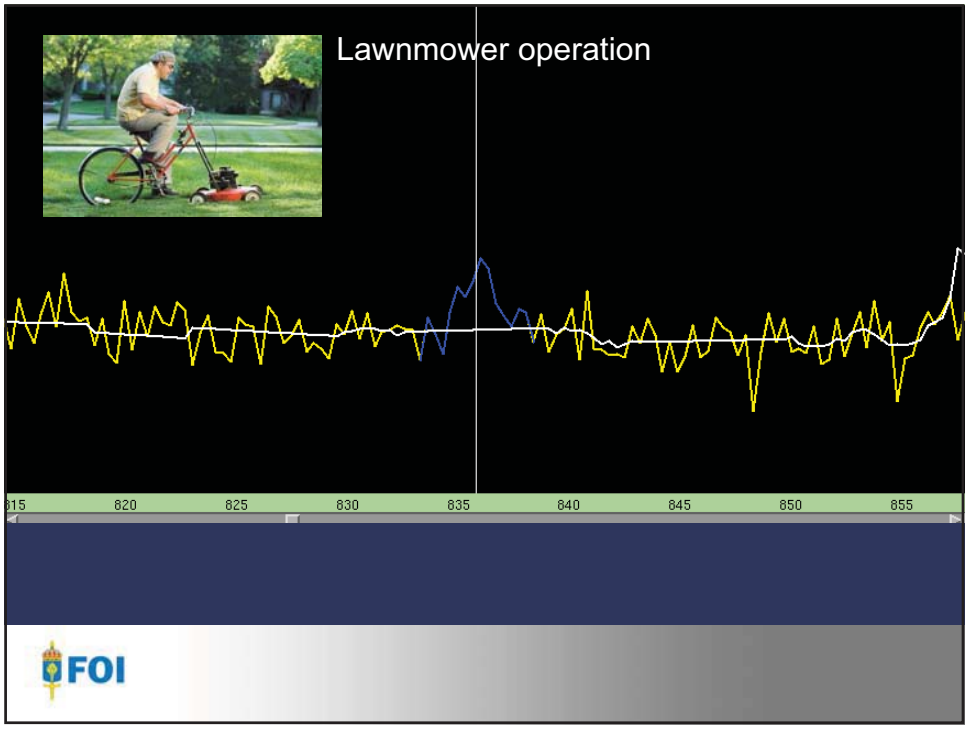
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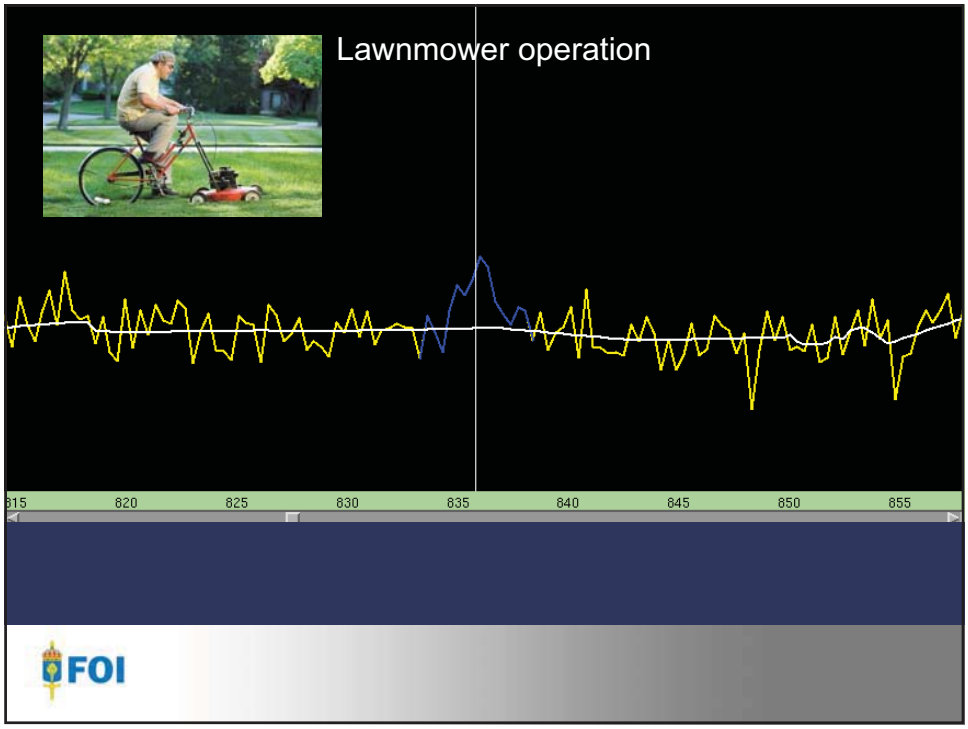
Lawnmower operation
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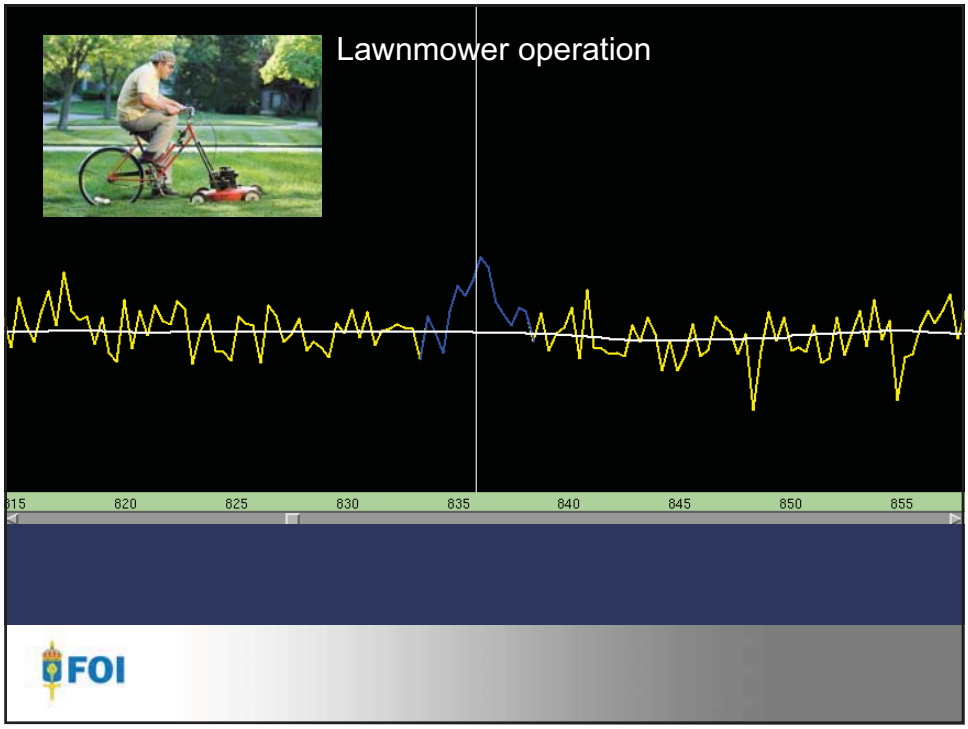
Lawnmower operation
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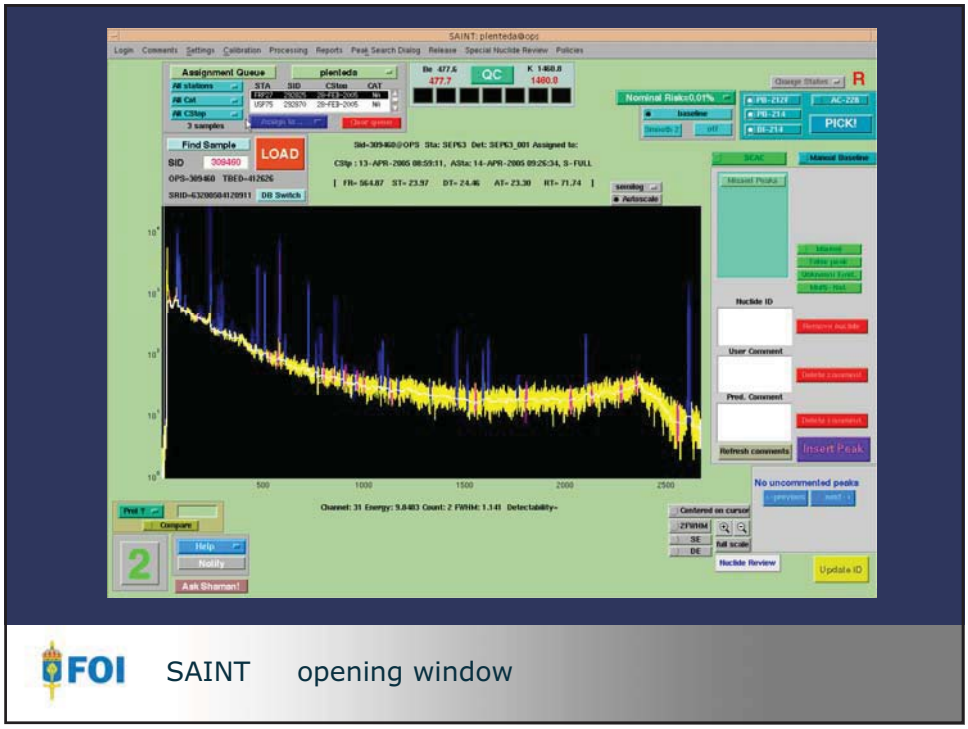
SAINT: plenteda@ops
Assignment Queue
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Find Sample
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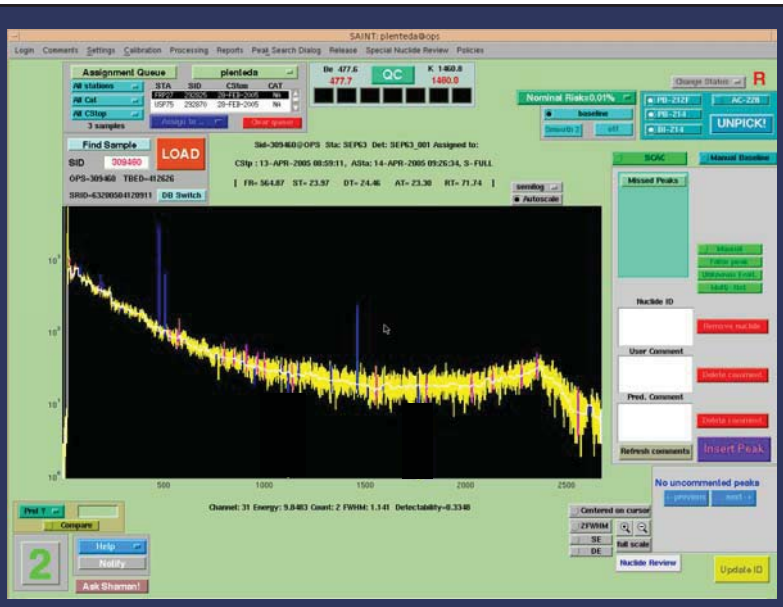
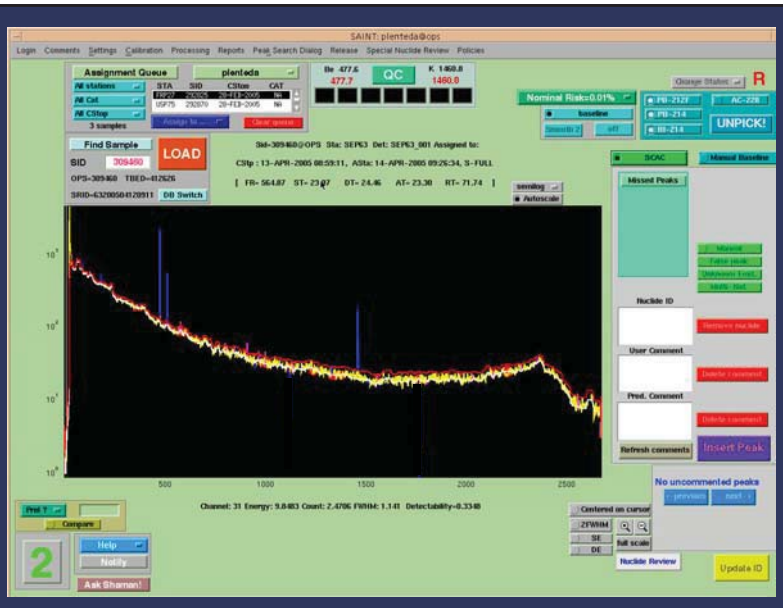
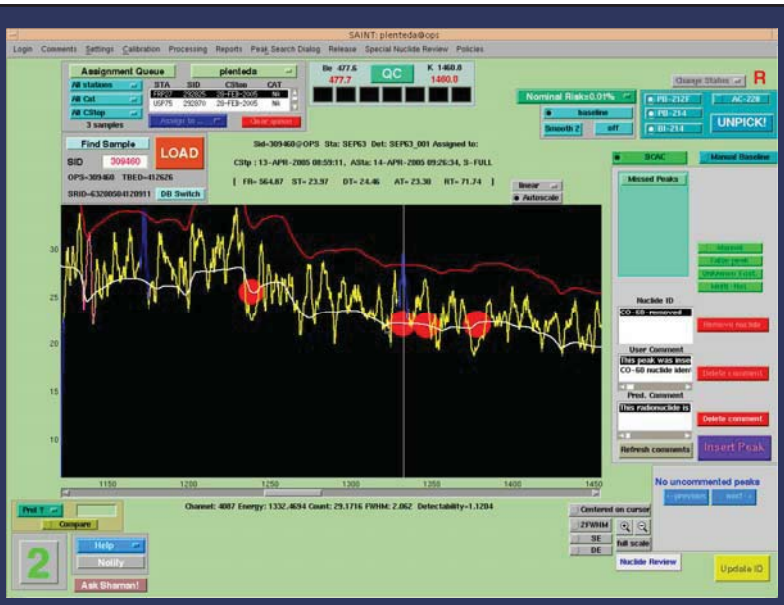
PICK!
Insert Peak
No uncommented peaks
Update ID
FOI
SAINT opening window



FOI SAINT spectrum picked



FOI SAINT SCAC-LCC



FOI SAINT SCAC-LCC

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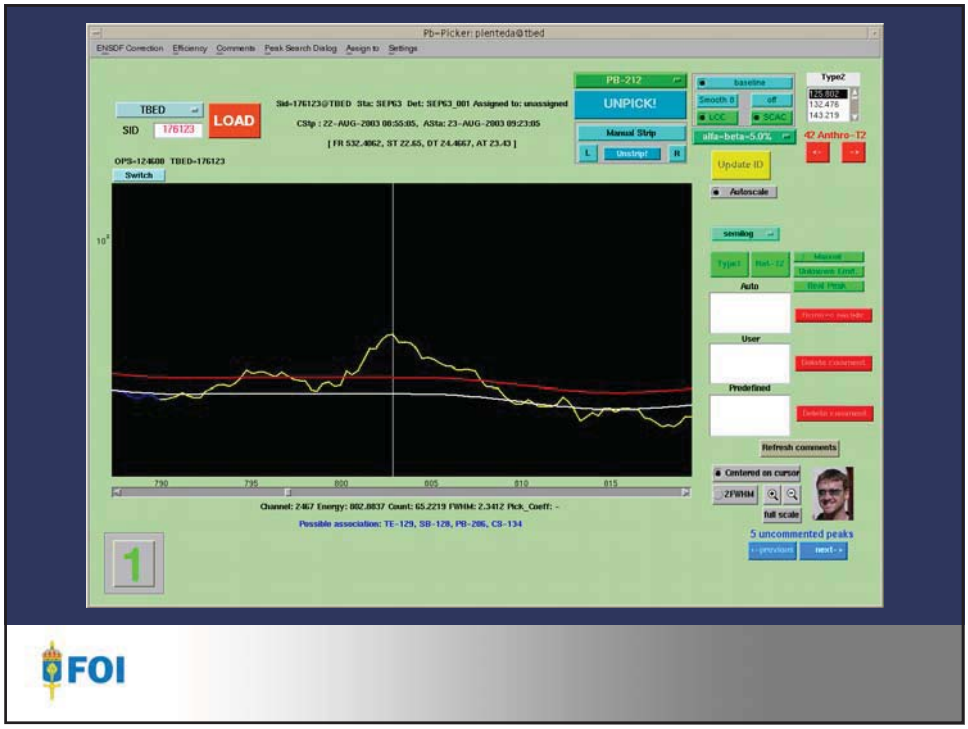
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OPS=124608 TBED=176123
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Possible association: TE-129, SB-128, PB-206, CS-134
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Pb-Picker: plenteda@ttbed
ENSDF Correction
Efficiency
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Sid=176123@TBED Sta: SEP63 Det: SEP63_001 Assigned to: unassigned
CStp : 22-AUG-2003 00:55:05, AStp: 23-AUG-2003 09:23:05
[FR 532.4062, ST 22.65, DT 24.4667, AT 23.43]
OPS=124608 TBED=176123
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Channel: 2467 Energy: 802.8837 Count: 65.2219 FWHM: 2.3412 Pick_Coeff: -
Possible association: TE-129, SB-128, PB-206, CS-134
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Thank you

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Attachment 4

GammaSem2010

A Nordic seminar for users of gamma spectrometry

Book of abstracts

Kjeller, 28-29 September 2010

True Coincidences and a Decent Currie

Lars-Erik De Geer
Research Director, Ph.D.
Division of Defence & Security, Systems and Technology
FOI, Swedish Defence Research Agency

Tel.: +46 8 555 03 444
E-mail: ledg@foi.se

This lecture will cover developments I led and worked for during a couple of years at the beginning of this century at the Provisional Technical Secretariat (PTS) for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) in Vienna.

In laboratory-based environmental gamma spectroscopy we normally work with weak samples that require a close detector – sample arrangement. That also makes true coincidence summation a visible problem for many nuclides. There are a lot of schemes and programs to deal with this, but the lecture will focus on the one we developed in-house that is based on a two-step Monte-Carlo process where both decay and radiation transport are simulated.

Time permitting, I will also dwell on Currie detection criteria in gamma spectroscopy. Currie's classical paper from 1968 deals with single-channel analyzers and it is not straight-forward to apply it to spectroscopic data. At CTBTO with its political environment we had to define this as rigorously as we possibly could and we also had to understand the effects of erroneously detecting peaks at conventional risks as high as 5 % across a full 8192 channel spectrum.

Expert System SHAMAN and Comparison of its Coincidence Correction to KORSUM

Jarmo Ala-Heikkilä, Pertti Aarnio
Aalto University School of Science and Technology, Department of Applied Physics

SHAMAN is an expert system for radionuclide identification. It has been developed at Aalto University (formerly Helsinki University of Technology, TKK) since 1987. SHAMAN needs a gamma-ray spectrum analysis tool as its preprocessor, typically SAMPO or UniSAMPO that have also been developed by the same research group. SHAMAN is used world-wide mainly in airborne radioactivity measurement networks.

SHAMAN has been designed to replace the human expert in gamma-ray spectrum interpretation as far as possible. It uses a comprehensive nuclide library (3,600 nuclides, 80,000 gamma-ray and X-ray lines) and conservative inference rules. The aim of SHAMAN is to find the most probable nuclide composition that explains the spectrum peaks. In particular with air filter spectra, the automated results of UniSAMPO-SHAMAN are very close to the goal.

SHAMAN features background subtraction, coincidence summing correction, and self-absorption correction. Additionally, it can estimate the sizes of sum peaks and escape peaks. The output reports of SHAMAN are fully tailorable and the analysis procedures can be scripted to enable a non-interactive analysis. SHAMAN also supports a publicly available SQL database schema called LINSSI that is separately presented at this seminar.

Coincidence summing is important in close geometries, typically used in environmental monitoring, and for complex decay schemes. In SHAMAN, the method of Andreev *et al.* [IET 25 (1972)] for coincidence correction has been implemented. Decay schemes for 120 important nuclides have been extracted from ENSDF. Total efficiency that is needed in the calculation in addition to peak efficiency can be input to SHAMAN, but if it is not available, SHAMAN can estimate total efficiency from peak efficiency.

SHAMAN's coincidence correction calculation was compared to KORSUM implemented by K. Debertin *et al.* [NIM 158 (1979)]. A set of 25 nuclides and their 291 gamma-ray lines was used in the comparison. Identical decay schemes and calibrations were used as input to reveal essential differences, if any, in the results.

It was found that coincidence correction factors calculated by SHAMAN and KORSUM were within 1 % of each other for 89 % of the gamma-ray lines. All but 4 of 291 values were within 3 % of each other, i.e., within typical uncertainties from other sources. The 4 differing cases were explained with inaccuracy in efficiency extrapolation, a metastable state, and a gamma line matching problem. It can be concluded that the coincidence correction calculation in SHAMAN is consistent with that in KORSUM. The differences in results are due to differences in input. The calculation is especially sensitive to the decay scheme details.

Acknowledgement:
The KORSUM results were kindly provided to us by Weihua Zhang (Radiation Protection Bureau, Health Canada).

Further reading:

P.A. Aarnio *et al.*, "Analysis Pipeline for Air Filter Gamma-Ray Spectra from the CTBT Verification Network". J. Radioanal. Nucl. Chem. 263 (2005).

P.A. Aarnio *et al.*, "Performance of UniSampo-Shaman with Gamma-Ray Spectra Containing Known Traces of Fission Products". J. Radioanal. Nucl. Chem. 276 (2008).

J.J Ala-Heikkila, "Analysis Methods for Airborne Radioactivity". Doctoral Dissertation, Helsinki University of Technology, TKK Dissertations 129, Espoo 2008; available at http://lib.tkk.fi/Diss/2008/isbn9789512294404/

Cascade Summing Corrections with Genie-2000

Henrik Jäderström
Canberra Solutions AB

Several nuclides emit two or more gammas within a timeframe much to short for a germanium detector to resolve them. If more than one hit the detector the energy from both will be registered. This can lead to either summing out, to few pulses in the photo peak, or summing in to many pulses. Both cases lead to a wrong determination of the activity.

Canberra's gamma spectroscopy software Genie-2000 contains a method for correcting for cascade summing. The method has recently been extended to lower energy to be able to better correct for x-ray summing. In addition the need for performing peak-to-total calibrations have been eliminated. These new features will be presented together with a review of the Canberra Cascade Summing Correction method.

A summary from the ALMERA workshop on coincidence summing and geometry correction in gamma ray spectrometry

Rajdeep Sidhu
Institute for Energy Technology, P.O.Box 40, NO-2027 Kjeller, Norway

During the 6th ALMERA coordination meeting in November 2009, the ALMERA participants requested the IAEA to organize workshop to discuss coincidence summing and geometry correction in gamma ray spectrometry. The workshop took place in the IAEA's Laboratories in Seibersdorf (Austria), from 19 to 23 July 2010.

The workshop was addressed to experienced scientists in gamma spectrometry and represented a possibility for the ALMERA members to work on practical exercises, and to refresh and update their knowledge and skills in coincidence summing and geometry correction in gamma ray spectrometry. It also created an opportunity for the ALMERA scientists to initiate collaboration with other laboratories.

The following topics were addressed during the workshop:

1. True coincidence summing correction: Theory
2. True coincidence summing correction: Experimental
3. Geometry correction: Theory
4. Geometry correction: Experimental
5. Self absorption corrections: Theory
6. Self absorption corrections: Experimental
7. Decision threshold and detection limit

This presentation gives a short summary of the workshop.

Geological mapping using airborne gamma ray spectrometry

V.C. Baranwal[1], R.J. Watson[1], M.A. Smethurst[1,2] and J.S. Rønning[1,3]
[1] Geological Survey of Norway, Postboks 6315 Sluppen, 7491 Trondheim
[2] Avalonia Geophysics, University of Exeter Cornwall Campus, Penryn, TR10 9EZ, UK
[3] Norwegian University of Science and Technology (NTNU), Trondheim

At the Geological Survey of Norway (NGU), we use airborne gamma ray spectrometry (AGRS) for geological mapping. Till date, we used a 256 channel Exploranium GR820 gamma ray spectrometer with sodium iodide detector packs with a total crystal volume of 20.9 l (16.7 l downward and 4.2 l upward detector). A full spectrum of energy from 0.2 MeV to 3 MeV is recorded in channels 0 to 254 and the total counts for energies above 3 MeV is recorded in channel 255 as cosmic radiation. From this year on, the spectrometer is upgraded by Radiation Solutions Inc. to a RSX-5 which has possibility to operate it in 1024 channels. General interest of geological mapping is to map naturally occurring radioelements K-40, U-238 and Th-232, however it can also be used for nuclear fallout mapping and for searching of radioactive objects. At NGU, we use AGRS for mapping of natural radioelement and manmade Cs falldown. Our equipment is a part of the National Nuclear Accident Preparedness Organization.

We performed helicopter-borne geophysical surveys in the autumn, 2008 and summer, 2009 for natural radioelement mapping around Kongsberg area in south of Norway. Collected data was processed for corrections due to radiations from cosmic, aircraft and radon in addition of other general corrections of AGRS. The Radon correction was performed with the help of upward detector measurements. It is learnt that there was different seasonal variation of airborne radon present in the area which affects especially U measurements. Therefore different calibration coefficients for airborne radon were calculated for two seasons and applied separately to the dataset collected in the different season. Working out the amount of airborne radon in different season helped in leveling the concentration of U for whole area of the survey.

Mobile gamma ray spectrometry and the efficiency of real-time data processing in describing the natural background signal and highlighting anthropogenic nuclides

M.A. Smethurst[1,2], R.J. Watson[1], V.C. Baranwal[1] and J.S. Rønning[1]
[1] Geological Survey of Norway, Postboks 6315 Sluppen, 7491 Trondheim
[2] Avalonia Geophysics, University of Exeter Cornwall Campus, Penryn, TR10 9EZ, UK

Mobile gamma ray spectrometry is a rapid and efficient way of mapping spatially distributed fallout during and after a nuclear accident and locating lost or hidden isolated sources of radiation. In 1999 the Geological Survey of Norway developed a mobile measuring system called "GammaLog" that is now a key element in emergency mobile mapping in Norway, operated by the Geological Survey of Norway, Norwegian Radiation Protection Authority and Norwegian Air Force. GammaLog can be deployed by car/van, helicopter and aeroplane. In Norway the airborne platforms are likely to be the most effective in the majority of emergency situations.

GammaLog depends on a large NaI detector and spectrometer system with the option for an additional complementary HpGe instrument operating at a lower measuring frequency. Given the considerable spatial variation in background natural signal in Norway it is essential to divide the observed gamma ray spectra into natural and anthropogenic components in real time. This gives the operators the ability to (1) differentiate between natural and man-made nuclides (2) avoid entering hazardous areas, (3) dynamically adjust surveying strategy, (4) identify and report contamination while surveying, (5) make a first order assessment of radiation doses at ground level.

The presentation will focus on the method employed by GammaLog to isolate the anthropogenic signal. First, a method founded on conventional window stripping is used to produce a model natural gamma spectrum, assuming it is the sum of signals from naturally occuring uranium and thorium daughters (including airborne radon), potassium-40 and cosmic radiation. The difference between this and the observed spectrum is assumed to relate to anthropogenic sources. This difference spectrum can be displayed in a number of ways to highlight local and weak anthropogenic sources as well as feint distributed fallout.

Given that the measuring cycle for the NaI instrument is 1 second, real time processing must be kept simple to leave computer processing capacity free for other tasks. We will show this approach performs using examples of real field measurements acquired at exercises carried out over the last 12 years. We will show situations where the processing technique works well, explain why, and where it fails and show how we guard against misinterpretation of data in these situations.

Uncertainties in mobile gamma spectrometry

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Calibration of mobile equipment for measurement of gamma radiation differs in many ways from calibration of laboratory equipment with the same general purpose. Factors as source geometry, standardised measurement procedures and the importance of low level background that in a laboratory measurement situation is given the utmost attention and are of critical importance for laboratory certification take on an altogether different importance in mobile gamma spectrometry.

In mobile gamma spectrometry used for emergency purposes, i.e. purposes where radiation from natural radionuclides is considered part of the background, there is neither a low level background level, nor a constant background level. For these systems, background means not only background from soil, roads etc. but also contributions from radioactive gases in the air. Radon daughters, that are not only considered a health risk, are by far the larger contribution to background variations during a series of measurements. And they move with the wind, out of the measurement area and into the measurement area and possibly precipitates. A simple dose rate measurement on the same physical position outdoors may vary by a factor of two during a thunderclasp of heavy rains.
In mobile gamma spectrometry used for emergency purposes, also there is no physical source definition and no standard measurement geometry exists. The distance from the detector to the source is in principle unknown and measurements may be made primarily in order just to find the source, e.g. orpaned source. The source may also be an area source with radionuclides smeared out in uneven distribution on a ground surface of unknown area size. Calculations and estimations of point source strengths and radionuclide contamination concentrations on surfaces represent two quite different types of procedures.

A nuclear fallout is in principle an area source for which large and theoretical calculation procedures does exist. In praxis, the area of land - seen from e.g. an altitude of 300 feet with a field of view of 500 meters around the measurement equipment - is not just one area but consists of many smaller areas. Some areas may be farmland, some forest, cities, motorways, etc.

Deposited radionuclides may be washed or blown off a contaminated smaller area very fast. In other areas, grass and plants may assimilate some of the radionuclides. At the bottom of mountains the radionuclides may well accumulate and create pools of radiation – hot spots.

When the source is defined, the relative position of the measurement equipment must be defined, too. For airborne surveys consecutive 1-sec-measurements may be distributed several hundred meters apart in the horizontal direction and also differ in the vertical distances between aircraft and ground level.

"What has been measured, how much and where?" becomes questions that lessen the importance of e.g. minimum detection levels in contrast to the importance of the personnel performing the measurements being skilled to evaluate the data materiel taking into account the appropriate influences from terrain, weather conditions, water bodies a.o. on the day the measurements were made.

Aspects affecting low-background measurements

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Gamma measurement of low activity environmental samples is a demanding task. In some cases the activity of the sample may be at the same level as background. In the case of anthropogenic nuclides measurement is some what easier since the prominent gamma peaks are not present in the background. The situation is much different when the interest lies in the normally occurring radioactive materials (NORMs). Small quantities of natural radioactivities in the background can disturb measurements significantly. Thus it is important know which factors contribute to the total background which ultimately determines the detection limits. Before measures of background reduction can be taken factors and their contribution effecting to total background must be understood.

A series of background measurements were conducted in order to determine contribution of different components in background. Also different measurement setups were tested in order to determine optimum setup. Constant background measurement time of 2880 minutes (48h) to allow exact comparison of measurements. The detector used in the measurements was an Ortec HPGe installed inside an ultra-low background lead castle. Lead bricks on the floor were used to reduce the radiation from the floor, plastic disks were used to slow down atmospheric neutrons together with a borated steel plate, nitrogen flush was used to reduce radon induced background inside the lead castle, measurement room radon level was monitored continuously.

The results of these measurements will be discussed in the presentation.

LINSSI - Relational Database for Gamma-Ray Spectrometry

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LINSSI is a relational SQL database for gamma-ray spectrometry, including extensions for alpha and beta-gamma coincidence spectrometry. Its general features also allow further easy extensions to other fields of radiation measurement and analysis. LINSSI is designed to cover the whole production chain from sample preparation to final analysis results. Static or mobile sampling and measurement with multiple sample types are supported. In addition, each sample can be split or combined any number of times. A sample may be measured multiple times and each measurement multiply analyzed as well. With LINSSI, measurement setups with detectors, shields, attenuators and source geometries can be defined. Full control of calibrations, their histories and tracing of each calibration point back to its corresponding analysis and calibration measurement are also available. LINSSI supports multiple facilities including, but not limited to, laboratories, sampling stations, in-situ sampling and measurement, mobile equipment with real time GPS tracking, etc. In addition, transport and tracking of samples between and inside facilities can be controlled. Tables are also available for formal inter-facility document exchange.

A traditional solution for data management in gamma-ray spectrum analysis has been a file based system where each spectrum with its associated information and analysis results is stored in a set of files. In addition, paper copies have been filed as legally binding documents. When the number of files in this kind of system grows, searching specific data from them becomes quite complicated unless some order is imposed. This can be obtained with relational database system consisting of the definition of database tables, database scripts and standard spectrometry software. The database definition [1] is rigid but extendable. The scripts [2], on the other hand, are flexible and easy to write when new needs arise.

LINSSI also provides support for an automated analysis pipeline, where spectra received by email are automatically analyzed and stored in the database. STUK, for instance, has set up an analysis pipeline for Comprehensive Nuclear-Test-Ban Treaty air-filter spectra. That pipeline, using Shaman analysis software, which is separately presented at this seminar, operates continuously and has analyzed hundreds of thousands of spectra and stored the results in LINSSI.

LINSSI has been developed as a common effort of Aalto University School of Science and Technology (former Helsinki University of Technology (TKK)), Finnish Radiation and Nuclear Safety Authority (STUK) and the Radiation Protection Bureau of Health Canada (HC). A LINSSI demonstration, database specifications, and and user scripts are available at http://linssi.hut.fi/.

[1] Pertti Aarnio, Jarmo Ala-Heikkilä, et al., LINSSI - SQL Database for Gamma-Ray Spectrometry, Part 1: Database, Version 2.2, Report TKK-F-A-861, 2010
[2] Pertti Aarnio, Jarmo Ala-Heikkilä, et al. LINSSI - SQL Database for Gamma-Ray Spectrometry, Part 2: Scripts and Interfaces, Version 2.2, Report TKK-F-A-861, 2010

Hand-held gamma spectrometry for assessing radon risk from building aggregates

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Radon levels in dwellings are associated with increased incidence of lung cancer, and building materials can be a significant contributor to indoor Radon concentrations. To ensure compliance with recommended Radon levels, NGU and Statens strålevern have embarked on a study to assess radon risk from building aggregates. The study includes the investigation of methods of measuring radon potential from aggregates at production sites, including the use of hand-held gamma ray spectrometry. Such gamma ray measurements can be sensitive to the effects of background radiation from airborne radon and the surrounding environment, and we investigate the use of lead and plastic shielding configurations to correct for these effects.

An overview of NGU's role in the study will be presented, with emphasis on gamma ray measurement techniques.

International co-operation on the analysis of gamma spectra for malevolent radiological situations: NKS-MALRAD and testing the international use of the US TRIAGE system

Sigurður Emil Pálsson[1] and Mark Dowdall[2]
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The MALRAD activity was intended to provide an exercise activity with respect to gamma ray spectrometric response to malevolent situations involving radioactive sources. Such situations can often be characterised by high activity sources in difficult contexts where the response is by necessity conducted with less than optimal instrumentation. Seven scenarios were developed based on previous incidents where possible and gamma spectral data (both HPGe and low resolution) and other information was disseminated to participants who were given one week to respond to each scenario with as much information as possible. In total 14 individual laboratories responded. The majority of laboratories were in a position to satisfactorily identify sources where single sources were used in situations with no complicating factors. For those scenarios involving heavy shielding some difficulties were encountered due to distortion of the spectrum from that which would normally be viewed as characteristic for the isotope in question. Special nuclear materials such as reprocessed enriched uranium and weapons grade plutonium provided different challenges and there were indications in the responses from participants of unfamiliarity with these materials.

The U.S. Department of Energy / National Nuclear Security Administration (NNSA) has been providing an analytical service, TRIAGE, for many years within the US, whereby measurement data and additional information can be submitted and an evaluation is provided promptly, typically within an hour. This service is now available internationally through the IAEA or via direct contacts with the NNSA. The Icelandic Radiation Safety Authority (IRSA) and NNSA decided to conduct an exercise using the NKS-B MalRad scenarios and data for testing international use of the TRIAGE system. IRSA provided the information and data to TRIAGE on each of the 7 scenarios as had been done in the MalRad exercise, here however only one scenario was submitted at each time. The TRIAGE performed well, giving promptly as accurate results as could be expected by the given data.

The 7 scenarios will be presented and what type of difficulties the participants seemed to have analysing them. The MALRAD activity showed how it was possible to generate data corresponding to realistic situations using Monte Carlo methods, data which would in some cases have been difficult to obtain via measurements. The exercise also gave the participants an opportunity to practice receiving and evaluating outside data, which can be important during an emergency. The MALRAD test data created can be used for subsequent training and exercises, as was demonstrated with the IRSA-NNSA exercise.

The activity is described in the NKS report NKS-207, M. Dowdall *et al*: Proficiency Test in the Analysis of Gamma Spectra for Malevolent Radiological Situations (MALRAD) and a paper has been accepted for publication by Applied Radiation and Isotopes.

Gamma spectrometric measurement of nuclear materials

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Characterization of nuclear material is important in many applications, such as nuclear safeguards and illicit trafficking. Nuclear material includes e.g. plutonium, uranium and U-233. Basic characterization of nuclear materials can be done using e.g. high resolution gamma spectrometry. Such a measurement will give the isotopic composition and the age of the material. Implementation and development of methods has been done at FOI. A method for measuring U-233 (age and U-232 content) was developed. Furthermore, a method for assessing the uncertainty in uranium isotopic measurements using gamma spectrometry was developed and evaluated.

The presentation will give the fundamental basis for these kind of measurements as well as the results from the methods developed at FOI.

Analysis of samples containing a mixture of biological, chemical and radiological agents ("mixed samples")

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The Norwegian Defence Research Establishment (FFI) has developed and implemented a set of procedures and routines in house for handling and analysis of "CBR mixed samples".

Efficient response and national preparedness against biological, chemical and radiological (CBR) threat agents is dependent on reliable detection and identification methods of any sample to be analysed. The analysis of several CBR agents simultaneously and/or immediately in sequence is more challenging compared to analyses of a sample solely containing one agent. NATO has recognized this challenge and has taken effort to strengthen the alliance's competence on handling samples containing a mixture of CBR agents (mixed samples) by organizing exercises among the participating nations of the NATO SIBCRA Subgroup (Sampling and Identification of Biological, Chemical and Radiological Agents). These exercises were initiated in 2007.

Handling such mixed samples involves complex problems. Mixed samples require strict safety procedures. Analysis techniques used for one type of agent might destroy other types of agents. Screening for radioactivity is no-destructive and can therefore be done at an early stage in the process, but before a more thorough analysis is performed, the samples should be treated to avoid contamination of equipment and risk to personnel from chemical and biological agents.

The FFI has participated in two NATO laboratory exercises. The procedures followed and the results from these exercises will be presented.

Verification of fissile materials

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The verification technologies are important in authenticating the presence of the fissile materials using non-destructive assay. The International Atomic Energy Agency (IAEA) has developed methods and technologies as a part of their safeguards procedures, employed for the verification of declared fissile material content. However, the methods and procedures for the verification of nuclear weapons (mainly consisted of weapon grade plutonium (WGPu)) are not well developed.

In order to develop the nuclear warheads verification methods, the concept of information barrier is normally employed. Information barrier (IB) is a combination of hardware, software, and procedures that protects all sensitive information but provides a small set of non-sensitive information, required by the monitoring authority. The Norwegian Study Group on Nonproliferation and Disarmament (NorNed) and the Atomic Weapons Establishment (AWE) are working jointly on an Information Barrier (IB) project. The basic purpose of the project is to implement the non-Nuclear Proliferation Treaty (NPT) article VI, which concerns the nuclear disarmament under strict and effective international control.

The NordNed and AWE started its work in designing and building a prototype IB. The gamma-spectroscopy method was used to detect and verify the presence of ^{60}Co in a sample. In another prototype, the groups have identified the abundance ratio between two ^{60}Co and ^{22}Na sources by measuring the peaks at 1.17 MeV for ^{60}Co and 1.2 MeV for ^{22}Na. The relative count rates of these peaks were used to deduce the relative abundance of Co and Na in the sample. The goal of these prototype IBs is to detect radiometric signatures from a surrogate radioactive source and give a yes/no response to a declared standard.

In order to extend the idea for the identification and verification of plutonium isotopes, the picture becomes more complicated. The weapon grade plutonium (WgPu) is characterized by the presence of a large amount of ^{239}Pu (ca. 93%) and lesser amounts of ^{240}Pu (ca. 6%). The gamma-ray energy spectrum of these isotopes shows various superimposed gamma –rays from 59 keV to 900 keV. So, the simple analysis as in the Co and Na verification would not be applicable here.

The process of verification of the weapon grade fissile material is simplified by searching predefined attributes. The following are the important attributes for the verification of WGPu: 1) the presence of ^{239}Pu, 2) the isotopic ratio between ^{239}Pu and ^{240}Pu, 3) the age of the plutonium, characterized by relative amount of ^{241}Am, 4) the minimum mass threshold of ^{239}Pu isotope, and 5) the presence of metallic plutonium. Therefore, a detailed spectroscopic analysis of plutonium isotopes is required. Additionally, one needs to model the count rates of characteristic peaks for variable isotopic composition and variable shielding conditions. These goals are very challenging keeping in mind the restricted access to plutonium isotopes.

The safeguards inspectors of the IAEA have, during inspections, the possibility to measure the entire spectrum. This is normally done with non-irradiated fuel, both uranium and mixed oxide (MOX) fuel. Such nuclear materials are declared under safeguards from a State to the IAEA. The

enrichment, isotopic content etc. in this material is known, and then verified by the IAEA through gamma-ray spectrum.

Weapon grade plutonium and uranium has not been declared under safeguards. These materials come under the military control in the Nuclear Weapon States (NWS). Therefore, characteristics of these materials that may be helpful for authenticating their presence at a site, are unknown.

In the present talk the developments in establishing a method of WGPu verification will be discussed.

Pu Lx spectroscopy in the presence of other radioisotopes

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Technical University of Denmark – DTU

Analysis of actinides, primarily Pu isotopes and Am-241, may be done using a low-enery HPGe-detector using gamma-lines and/or Lx-lines. In many applications the actinide isotopes are ocurring together with other radioisotopes creating potential interferences by their emission of gamma-rays, characteristic X-rays and even through beta and conversion electron emission. The presentation gives some examples of interferences in analysis of actinide-containing material with different composition.

Report on GammaWiki as a source of information on gamma spectrometry

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Background:
Following the GammaSem seminar in 2009 and the establishment of various working groups, the Icelandic Radiation Safety Authority offered to set up wiki based web, the GammaWiki, and an associated web forum, GammaForum. The idea was that the GammaForum could be used as a discussion forum for individual groups as needed and the GammaWiki could be used by the group to publish material, whether still in draft or final versions.

Advantages of a wiki-approach for compiling information:
The system uses a database to store the contents of the web site and the system takes care of much of the administration a system manager would have to do in a "manual" system. The users only need to input material according to some simple rules (see below), the system does the rest. Some key features:

- Familiar interface (like Wikipedia)
- It is easy to input text (can be copied from other sources), nice appearance is controlled by a few formatting commands.
- Tables can easily be imported from web, PDF or Excel
- PDF files can be referred to as well as images.
- It is very easy and fast to get a list of all pages containing a given search term (like in Wikipedia)
- If a page gets long it is automatically gets a list of contents

The value of a wiki-based system increases as more material comes in, especially the search and the web linking. The problem with "hand coded" web sites (without a search function) on the other hand is that as more material gets in, finding it and navigating through the web can become tiresome.

The GammaWiki can be found at https://www.gr.is/wiki/GammaWiki/ and simple instructions for inputting material and editing (for those who have editing rights) at https://www.gr.is/wiki/GammaWiki/index.php/Editing_GammaWiki

Results and conclusions:
No use seems to have been made of GammaForum. At time of writing (early September 2010) the working groups have not published their material on the GammaWiki. Favourable comments have however been received concerning the concept and material that was published and more will be added before the seminar as it becomes available.

The use (including input of material and editing) will be demonstrated at the seminar and the question will be raised if GammaWiki, with input from others, should be continued.

GammaSem 2010: Working Group on true coincidence summation corrections

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Background:

At the GammaSem seminar in 2009, several key issues in gamma spectrometry were identified for follow up, among them true coincidence summation corrections (TCC), and working groups were established. No plan for the working group on TCC was set up at the seminar, but the group agreed on the following during spring 2010:

Primary goal of the TCC GammaSem working group:

1. Describe when TCC is needed.
2. How large error is produced if TCC is not used.
3. Produce guidelines on how to use TCC (for users of the major softwares Genie and GammaVision)

How to achieve this?

1. Write a short "guidance" on when TCC is needed → labs already using TCC.
2. Test the TCC calibration procedure presented by IRSA on GammaSem 2009 → labs using GammaVision.
3. Test TCC calibration for Genie → labs using Genie.
4. Intercomparison test, with and without TCC → all labs in TCC working group.

Results and conclusions:

Information on use of TCC was compiled, but there has been little or no response from the working group participants during the year that has passed. It is believed that most of the group members signed up because they wanted to learn more about TCC and eventually implement TCC in their own laboratories. Also, there were no funding made available for this work, and the group therefore agreed that the work should be accomplished only by e-mail communication. This has led to the fact that almost nothing has been done in the TCC working group.

This presentation will therefore mainly focus on pros and cons with the working group concept, and some ideas and suggestions for future work will be made.

GammaSem 2010: Working Group on uncertainties and detection limits

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Background:
The working group regarding uncertainties and detection limits was set-up in the last GammaSem meeting 2009 to find a platform where Nordic and Baltic laboratories could enhance the understanding of the uncertainty assessment of gamma ray spectrometry, and to improve the consistency in the use of detection limits aimed to make certainty statement of the analysis. Our first step was to elaborate and submit a questionnaire in order to obtain a diagnosis of how we operate on a day-to-day level regarding uncertainty analysis and detection limits. The questionnaire was basically divided into three categories of questions; *i.)* the extent to which software is used in the various steps of the gamma ray assessment, *ii.)* the uncertainty budgeting and the steps in the gamma spectrometry being considered; *iii.)* the use of detection limits that characterize the detectability of gamma rays of the detection set-up (detection limit) and the gamma ray assessment (critical limit).

Results and conclusions:
So far 9 laboratories participation in the GammaSem have responded. The outcome has been qualitatively assessed by the working group leaders. The results show that most laboratories have automatised the whole assessment chain from pulse acquisition to statement of activity, but that some laboratories still use in-house algorithms as a complement. The sources of uncertainty being considered can be ranged in order of decreasing fraction of use; counting statistics are considered by virtually all, about half of the responders consider the uncertainty in the efficiency and measuring normal, a third consider density and true coincidence correction. More than half the responders do not use the GUM formalism to evaluate the uncertainty in their gamma ray assessment. Another laboratory report an intention to use this algorithms. The alternative approach in stead of GUM varies between the responders; some have merged Type A and Type B but intent to make a distinction between, someone has not made any distinction or even considered such a distinction have been employed in the uncertainty budget. Regarding the use of detection limits, 7 of 9 reported the use of detection levels for *a priori* characterization of gamma detection sensitivity. The expressions vary and some of them are directly adopted from the gamma software used. Only 2 of 9 reported use of critical limit for *a posteriori* characterization of a gamma spectrometry assessment.

Conclusion:
From the response of the questionnaire it is obvious that we must work out a way to encourage the laboratories to complete their uncertainty budgeting and take all the steps in the assessment into consideration. We also need to increase the understanding of how the uncertainties are analytically evaluated. Even more concern should be taken to make the operators of the laboratories understand the principles behind the use of detection limits. This applies especially to the use of critical limit, which is central to all laboratories somehow connected to exemption measurements commissioned by industry or authorities

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Abstract

The project GammaSem was proposed to the NKS in 2008. The aim of the project was to arrange two seminars for users of gamma spectrometry, in 2009 and 2010. The seminars were meant to provide a forum for discussions and sharing of information on practical issues concerning gamma spectrometry and initiate a network of gamma spectrometry users in the Nordic countries. Such a Nordic network should strengthen the collaboration between laboratories and improve all participants' competence in practical gamma spectrometry.

Both seminars' focus was practical challenges met by the users themselves, rather than theoretical matters. Scientists and users of gamma spectrometry from all five Nordic countries were invited to the seminar, as well as scientist from the Baltic countries. A total of 65 people signed up for GammaSem 2010; representing 30 different universities, commercial companies, research institutes and authorities.

The working group concept as presented at last year's GammaSem, has not worked out as intended. The reason for this is probably because most of the laboratories that signed up to join the working groups, signed up because they wanted to learn more about the different subjects. In combination with the fact that no funding was made available for the working groups, it was difficult to establish goals on what to achieve. None of the working groups applied for funding from the NKS (or elsewhere) to establish separate projects.

There is a big need for more cooperation and for training within the field of gamma spectrometry. This fact has been proved through these two seminars, both by the many different topics that have been discussed, but also by the huge interest for participating in the suggested series of workshop. The GammaSem seminars have thus provided a much welcomed starting point for a broader Nordic collaboration.

Key words gamma spectrometry