Discussion on detection limits – Application of ISO 11929

European Commission, Joint Research Centre
Directorate for Nuclear Safety and security, JRC-Geel

Unit G2: Standards for nuclear safety, security and safeguards
The radionuclide metrology team of JRC-Geel
(RN-Team)

ICRM γ-ray spectrometry WG meeting, October 29, 2020.

Mikael Hult

Agenda (14:00-15:00)

- Introduction: Mikael Hult, EC, JRC-Geel.

- Presentation: “Implementing ISO11929 at our laboratories”, Michel Bruggeman, SCK CEN, Mol, Belgium

- Discussion:
  - Please bring up any relevant issue.
  - Ask a general question
  - Give an example from your lab
  - Make a (provocative) statement

- What this is not:
  - A course in ISO11929-1,2,3,4:2019

Examples of topics for discussion (1)

- Advantages of the new standard (2010 and/or 2019)
- Shortcomings of the new standard
- Need for an improved standard
- Status of implementation: How it is implemented in your lab?
- Question to manufacturer: How is 11929 implemented in your software?
- Explaining Bayesian statistics (and how to spell it)
- Recent examples where products have been removed from shelves due to radioactivity measurements (impact of critical levels)

Examples of topics for discussion (2)

- How is it done in fundamental physics (gravitational waves, neutrino detection etc.?
- What can we do “for Corona” (meaning “against”)
- How to report?
  - Activity + limit (which limit), only limit, explanation of limit?
- What about limits data calculated using different definitions?
- Any other comment/story?

“Very Old” Literature

L.A. Currie: Anal. Chem. 40(3):586-593 (1968)

L.A. Currie: Anal. Chimica Acta 391: 127-134 (1999)

C. Hurtgen, S. Jerome, M. Woods Appl. Rad. Isot 61: 145-149 (2000) “Revisiting Currie — how low can you go?” (ICRM-LLRMT conference, Mol, Belgium, 1999)

D.J. Strom, J.A. MacLellan: Health Physics 81(1):27-34(2001)

L.A. Currie: Appl. Rad. Isot 61: 145-149 (2004) (ICRM-LLRMT conference, Vienna, 2003)

L-E. de Geer: Appl. Rad. Isot 61: 151-160 (2004) “Currie detection limits in gamma-ray spectroscopy” (ICRM-LLRMT conference, Vienna, 2003)

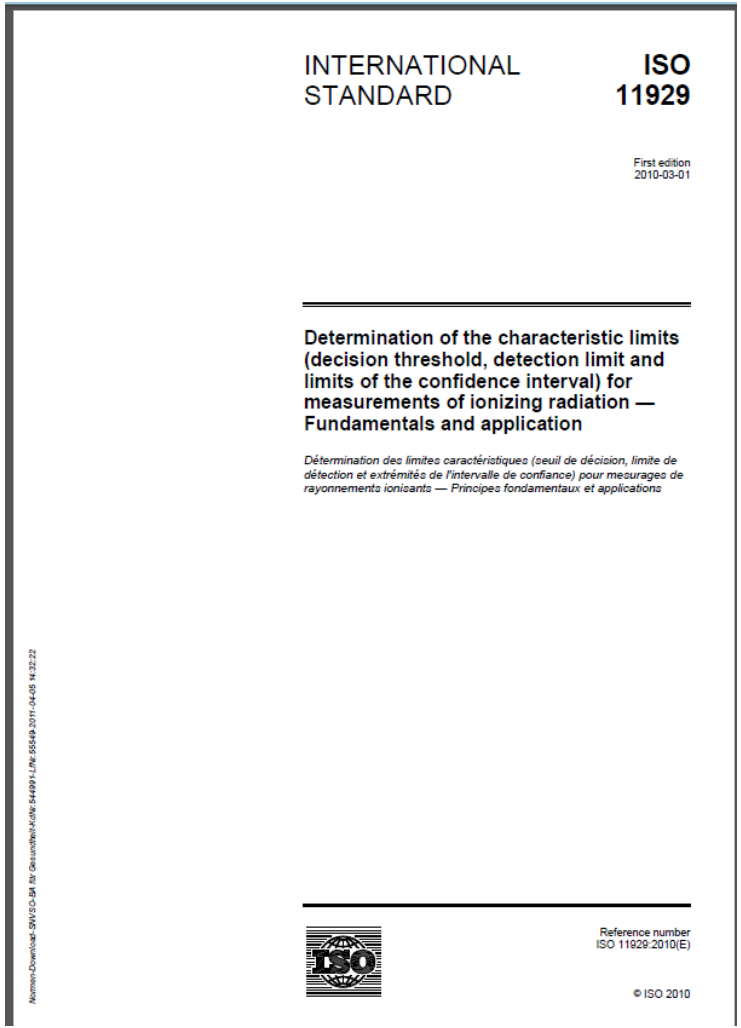
ISO 11929-3 (2000) “Determination of the detection limit and decision threshold for ionizing radiation measurements” –
Part 3: Fundamentals and application to counting measurements by high resolution gamma spectrometry, without the influence of sample treatment

“Old” Literature

Linda Peters. Diplomarbeit, 2012. http://sasse-stiftung.de/diplpete.pdf (supervisor Rolf Michel) *in German*.

ISO 11929 (2010) “Determination of characteristic limits (decision threshold, detection limit and limits of the confidence interval) for measurements of ionizing radiation – fundamentals and application

First talk by Prof. Michel at the 2015 ICRM conference (Vienna)


INTERNATIONAL STANDARD

ISO 11929

First edition
2010-03-01

Determination of the characteristic limits (decision threshold, detection limit and limits of the confidence interval) for measurements of ionizing radiation — Fundamentals and application

Détermination des limites caractéristiques (seuil de décision, limite de détection et extrémités de l'intervalle de confiance) pour mesurages de rayonnements ionisants — Principes fondamentaux et applications

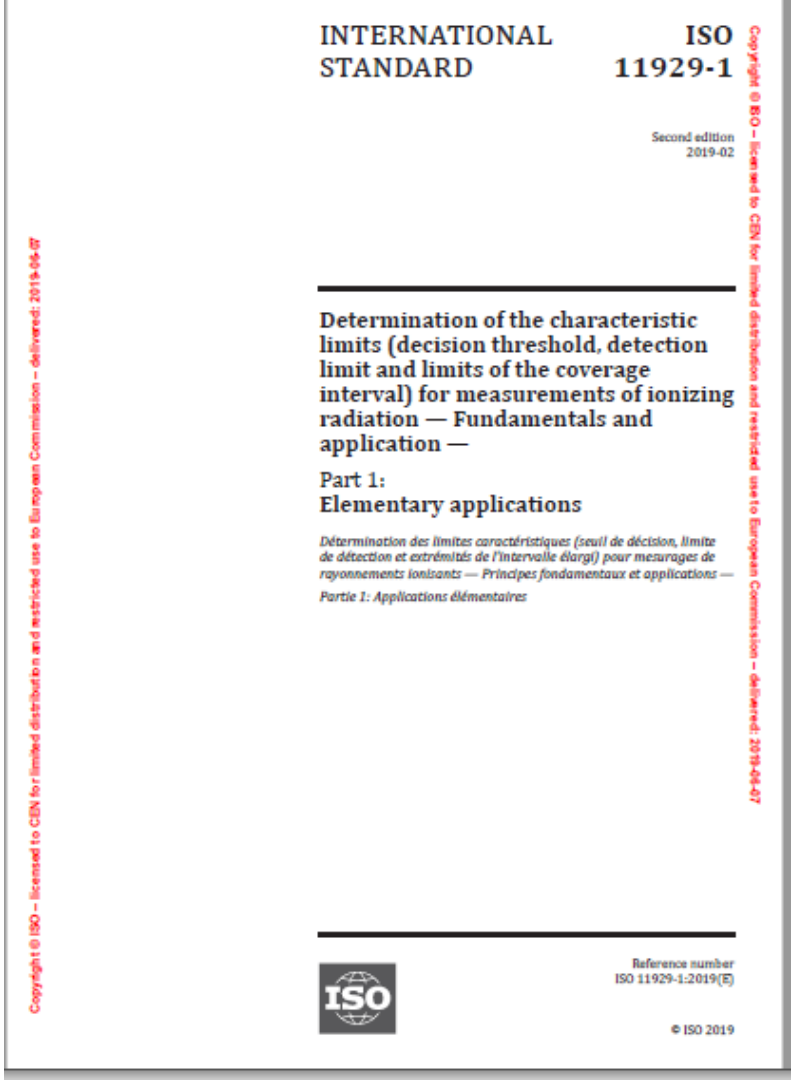
Reference number
ISO 11929:2010(E)

© ISO 2010

New 11929:2019

Part 1: Elementary applications
Part 2: Advanced applications
Part 3: Application to unfolding methods
Part 4: Guidance to the application

No major fundamental difference to 11929:2010. More explanations, examples and applications



New 11929:2019

Part 2: Advanced applications

Like 2010 but extended with

- explanations to Bayesian statistics
- evaluation of uncertainties according to ISO/IEC Guide 98-3-1

Part 3: Applications to unfolding methods

- especially for alpha-particle and gamma-ray spectrometry
- advice on how to deal with covarisance

New 11929:2019

Part 4: Guidance to the application

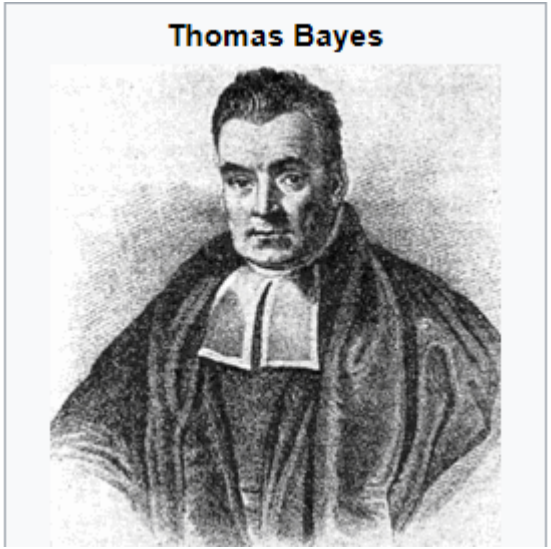
- Gives guidance to the application of the whole ISO 11929 series
- Summarizes shortly the general procedure
- Presents a wide range of numerical examples.

“New” Concept – Bayesian statistics

- Thomas Bayes (1701-1761)
- Bayes’s Theorem (1763 !!)
- …published by Richard Price

“***An Essay towards solving a Problem in the Doctrine of Chances*** “

Doctrine of chances = theory of probability



From Wikipedia:
During much of the 20th century, Bayesian methods were viewed unfavorably by many statisticians due to philosophical and practical considerations.
Many Bayesian methods required much computation to complete, and most methods that were widely used during the century were based on the frequentist interpretation.

Bayesian statistics

- Bayesian approach:

  From Wikipedia:
  The degree of belief may be based on prior knowledge about the event, such as the results of previous experiments, or on personal beliefs about the event

- Frequentists approach:

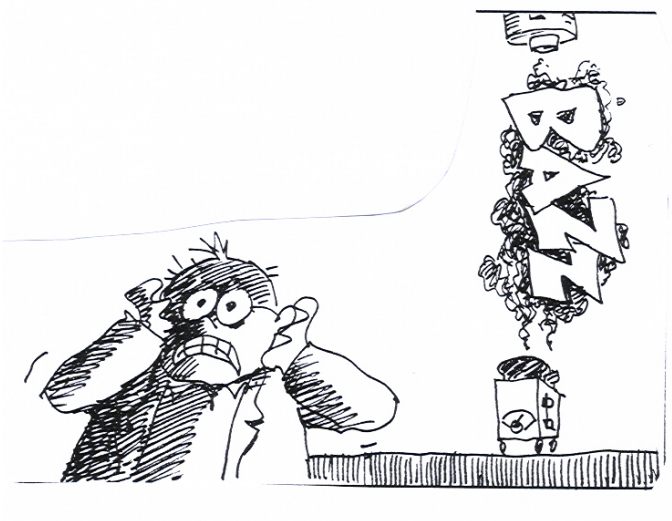
  From Wikipedia:
  probability is the limit of the relative frequency of an event after many trials

- **“a priori detection limit” (now Detection Limit, L_D)**

- **“a posteriori upper limit” (now Decision Threshold, L_C),**

Lloyd A. Currie: “Limits for Qualitative Detection and Quantitative Determination” Anal. Chem. Vol.40, No.3, 1968

Hypothesis test – false positive



ERROR TYPE I

α

Hypothesis test – false negative

ERROR TYPE II

β

DECISION THRESHOLD

There was nothing in the sample
What is the maximum amount that could be present?

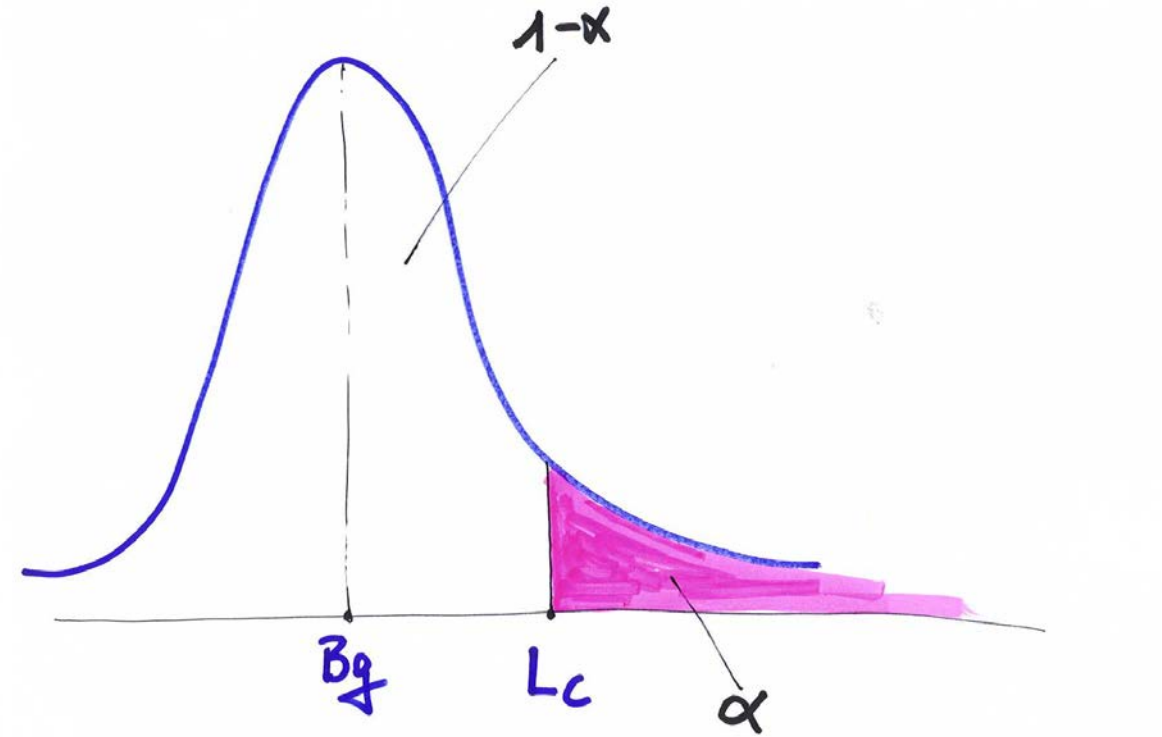
Is the net count significant?

Significance Level

$\alpha = 0.05$ (IUPAC recommended)

$\alpha = 0.01$

Significance Level



DETECTION LIMIT

What is the minimum amount this instrument can detect?

Power - still used?

$1 - \beta = 0.95$ (IUPAC recommended)

$1 - \beta = 0.99$

European Commission

Old Working Expressions

(but useful for back-of-an-envelope-calculation)

$$L_c = 2.33\ \sigma_b$$

$$L_d = 4.65\ \sigma_b$$

The Detection Limit
(with a certain power value)
defines your
measuring system

The Decision Threshold
(with a certain significance level)
defines your
result !

Decision threshold 11929:2000 – beware if you compare

Approximated formula (more exact)

Simplified formula

ISO 11929-3

$$R_n^* = \frac{k_{1-\alpha}^2}{2t}\frac{b}{2t}\left[1+\sqrt{\frac{4R_0 t}{k_{1-\alpha}}\frac{2l}{b}\left(1+\frac{2l}{b}\right)}\right] \qquad R_n^* = k_{1-\alpha}\sqrt{\frac{R_0}{t}\left(1+\frac{b}{2l}\right)}$$

DIN 25482-5

$$R_n^* = \frac{k_{1-\alpha}^2}{2t}\frac{b}{2l}\left[1+\sqrt{1+\frac{4R_0 t}{k_{1-\alpha}^2}\frac{2l}{b}\left(1+\frac{2l}{b}\right)}\right] \qquad R_n^* = k_{1-\alpha}\sqrt{\frac{R_0}{t}\left(1+\frac{b}{2l}\right)}$$

R_n^* Net effect counting rate, difference between gross and background effect counting rates

R_0 Background effect counting rate

α Probability of wrongly rejecting the hypothesis (error of the first kind)

$k_{1-\alpha}$ Quantile of normal distribution for error of the first kind

In our lab….

- Dr. Guillaume Lutter implemented the 11929:2010 in our analysis software - GLysis
- We can still compare with the old 11929:2000 (sometimes needed/asked)

Keep in touch

JRC PTs https://remon.jrc.ec.europa.eu/Services/Proficiency-Tests

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