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# Basic principles and background

**Sarajevo, Bosnia and Herzegovina**  
**29<sup>th</sup> September to 1<sup>st</sup> October 2010**

**Stephan Mieke**

# Basic principles and background

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- Measurement is present in almost every **human activity**, e.g. industrial, commercial, scientific, healthcare, safety and environmental.
- Measurement uncertainty is **associated** with any measurement.
- Measurement uncertainty plays a central role in **quality assessment** and quality standards.
- In **conformity assessment** the probability of making an incorrect decision based on the measurement and managing the consequential risks can be determined.
- As the **tolerances** applied in industrial production become more demanding, the role of measurement uncertainty becomes more important when assessing conformity to these tolerances.

# Basic principles and background

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- **No measurement is exact.** When a quantity is measured, the outcome depends on the measuring system, the measurement procedure, the skill of the operator, the environment, and other effects.
- Even if the quantity were to be measured several times, **a different indication value** would in general be **obtained each time**.
- The **dispersion** of the indication values would relate to **how well the measurement is made**. Their **average** would **provide an estimate of the true quantity value** that generally would be **more reliable** than an individual indication value.
- It is not possible to state how well the true value of the measurand is known, but **only how well it is believed to be known**. Measurement uncertainty can be described as a measure of how well one believes one knows the true value of the measurand. This **uncertainty reflects the incomplete knowledge of the measurand**.

# Basic principles and background

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## Outline

- JCGM documents and other literature
- Traceability chain
- Definitions in the VIM
- Bayesian statistic
- Probability density functions

# Basic principles and background

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# Basic ...

- JCGM documents and other literature

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Joint Committee for Guides in Metrology (**JCGM**):

- International Bureau of Weights and Measures (**BIPM**)
- International Electrotechnical Commission (**IEC**)
- International Federation of Clinical Chemistry and Laboratory Medicine (**IFCC**)
- International Laboratory Accreditation Cooperation (**ILAC**)
- International Organization for Standardization (**ISO**)
- International Union of Pure and Applied Chemistry (**IUPAC**)
- International Union of Pure and Applied Physics (**IUPAP**)
- International Organization of Legal Metrology (**OIML**)

# Basic ...

- JCGM documents and other literature

## Evaluation of measurement data

JCGM 100  
Guide to the expression  
of uncertainty in measurement  
(**GUM**)

JCGM 104  
An introduction to the GUM  
and related documents

JCGM 101  
Supplement 1 - Propagation  
of distributions using a  
Monte Carlo method

JCGM 102  
Supplement 2 - Models with  
any number of output values  
(unpublished)

JCGM 103  
Supplement 3 - Modelling  
(unpublished)

Also on the agenda, but not published:

- JCGM 105 - Concepts and basic principles
- JCGM 106 - The role of measurement uncertainty in conformity assessment
- JCGM 107 - Applications of the least-squares method

Download from: <http://www.bipm.org/en/publications/guides/gum.html>

# Basic ...

## - JCGM documents and other literature

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### JCGM 100

Guide to the expression  
of uncertainty in measurement  
(GUM)

#### pros

- calculation by hand is possible
- in the framework of the Guide exact

#### cons

- linearization of the mathematical model required

### JCGM 101

Supplement 1 - Propagation  
of distributions using a  
Monte Carlo method

#### pros

- no linearization of the mathematical model required
- shows the dispersion (PDF) of the result

#### cons

- requires software for practical application
- will give slightly different results every time the calculation is started



# Basic ... - JCGM documents and other literature

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Other literature:

- The Expression of Uncertainty and Confidence in Measurement (UKAS M3003)

<http://www.ukas.com/library/Technical-Information/Pubs-Technical-Articles/Pubs-List/M3003.pdf>

- International vocabulary of metrology - Basic and general concepts and associated terms (VIM, 3rd ed., JCGM 200:2008)

<http://www.bipm.org/en/publications/guides/vim.html>

- Metrology in short, 3rd edition

<http://www.euramet.org/index.php?id=mis>

# Basic principles and background

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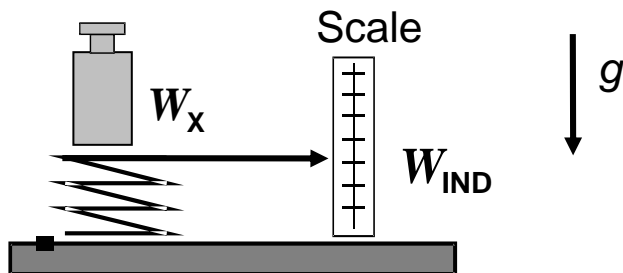
## Outline

- JCGM documents and other literature
- **Traceability chain**
- Definitions in the VIM
- Bayesian statistic
- Probability density functions

# Basic principles and ... - Traceability chain

## Methods of measurement

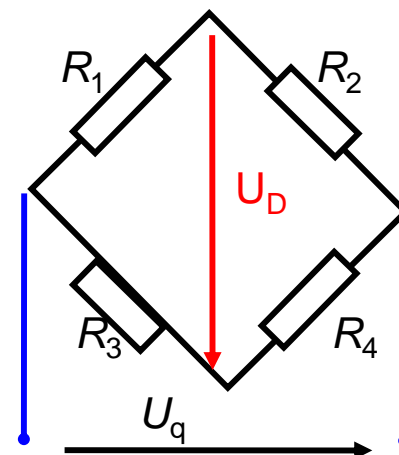
### • Indication



The quantity (object) is used itself to generate the indicated reaction.

### • Difference

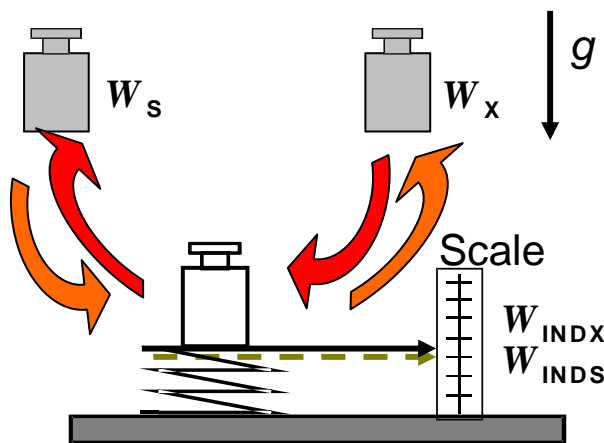
Example:  
Wheatstone bridge



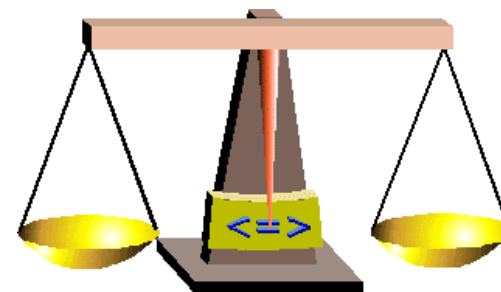
Determination of the difference of a quantity.

### • Substitution

The value of quantity is determined using a standard and by taking alternate readings



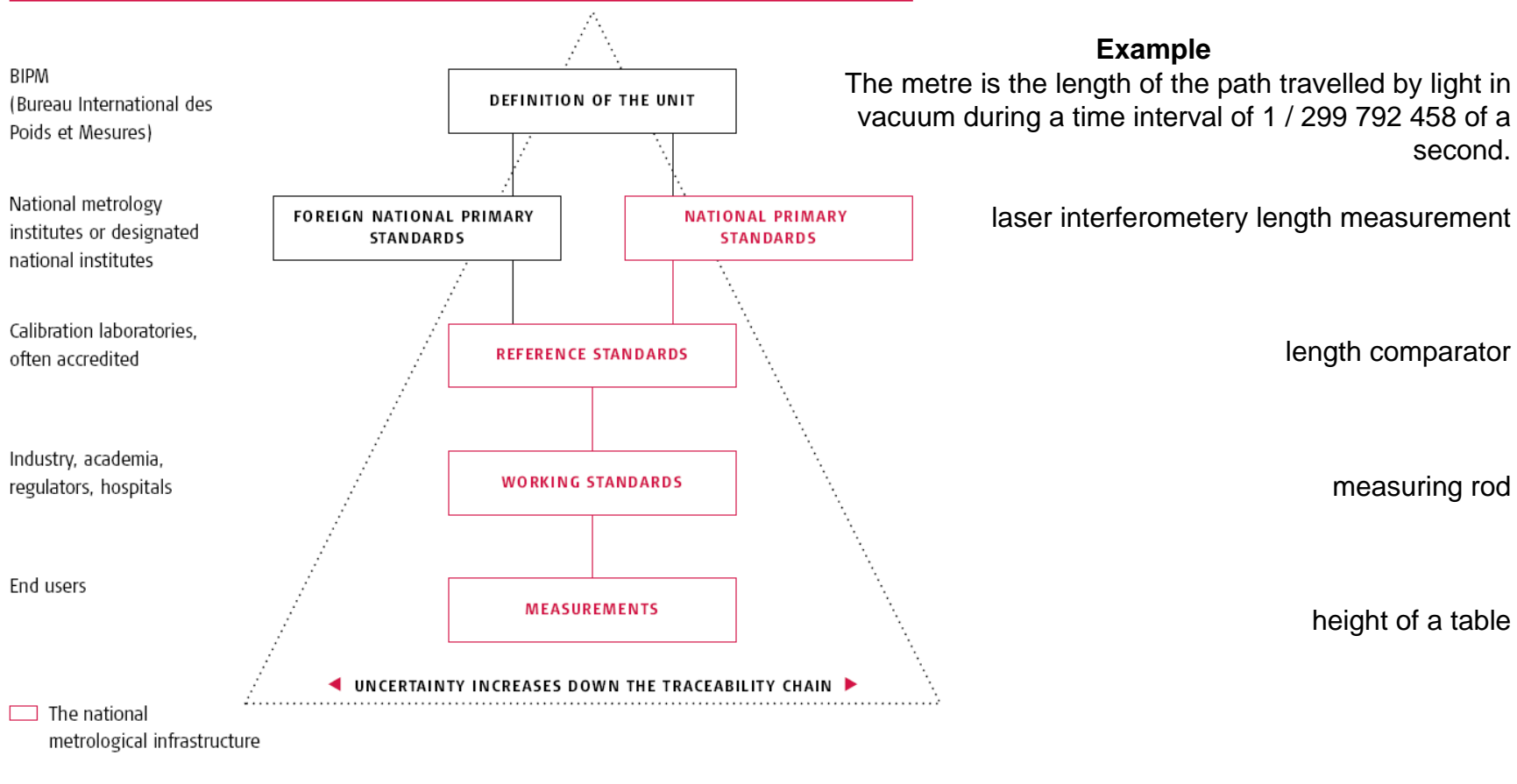
### • Compensation



Simultaneous direct comparison (null method)

# Basic principles and ... - Traceability chain

Figure 1: The traceability chain



## Traceability chain - the link to basic quantities

# Basic principles and background

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## Outline

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# Basic ... - Definitions in the VIM

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## 2.26 measurement uncertainty

non-negative parameter characterizing the **dispersion** of the quantity values being **attributed to a measurand**, based on the information used

Note: The definition in the GUM refers to the old VIM definition from 1993:

parameter, associated with the result of a measurement, that characterizes the dispersion of the values that could reasonably be attributed to the measurand

# Basic ... - Definitions in the VIM

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## 1.1 quantity

**property** of a phenomenon, body, or substance, where the property has a **magnitude** that can be expressed as a **number and a reference**

## 1.19 quantity value

number and reference together expressing magnitude of a **quantity**

## 2.3 measurand

**quantity** intended to be measured

# Basic ... - Definitions in the VIM

## 1.1 quantity

property of a phenomenon, body, or substance, where the property has a magnitude that can be expressed as a number and a reference

length, $l$	radius, $r$	radius of circle A, $r_A$ or $r(A)$
	wavelength, $\lambda$	wavelength of sodium D radiation, $\lambda_D$ or $\lambda(D;Na)$
energy, $E$	kinetic energy, $T$	kinetic energy of particle $i$ in a given system, $T_i$
	Heat, $Q$	heat of vaporization of sample $i$ of water, $Q_i$
electric charge, $Q$		electric charge of the proton, $e$
electric resistance, $R$		electric resistance of resistor $i$ in a given circuit, $R_i$
amount-of-substance concentration of entity B, $c_B$		amount-of-substance concentration of ethanol in wine sample $i$ , $c_i(C_2H_5OH)$
number concentration of entity B, $C_B$		number concentration of erythrocytes in blood sample $i$ , $C(Erys;B_i)$
Rockwell C hardness (150 kg load), $HRC(150\text{ kg})$		Rockwell C hardness of steel sample $i$ , $HRC_i(150\text{ kg})$



# Basic ... - Definitions in the VIM

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## 1.1 quantity

property of a phenomenon, body, or substance, where the property has a magnitude that can be expressed as a number and a reference

## 1.19 quantity value

number and reference together **expressing magnitude of a quantity**

EXAMPLE  
Mass of a given body: 0,152 kg or 152 g

## 2.3 measurand

quantity intended to be measured

# Basic ... - Definitions in the VIM

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## 2.16 measurement error

error of measurement  
error

measured quantity value **minus** a reference quantity value

# Basic ... - Definitions in the VIM

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## 2.19 random measurement error

random error of measurement

random error

component of measurement error that in replicate measurements **varies in an unpredictable manner**

NOTE 2 Random measurement errors of a set of replicate measurements form a distribution that **can be summarized by its expectation**, which is generally assumed to be zero, and **its variance** (*squared standard deviation*).

NOTE 3 Random measurement error equals **measurement error minus systematic measurement error**.

# Basic ... - Definitions in the VIM

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## 2.17 systematic measurement error

systematic error of measurement

systematic error

component of measurement error that in replicate measurements remains **constant or varies in a predictable manner**

NOTE 2 Systematic measurement error, and its causes, can be known or unknown. A **correction** can be applied **to compensate** for a known systematic measurement error.

NOTE 3 Systematic measurement error equals **measurement error minus random measurement error**.

# Basic ... - Definitions in the VIM

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## 2.21 measurement repeatability

repeatability

measurement precision under a set of **repeatability conditions** of measurement

## 2.20 repeatability condition of measurement

repeatability condition

condition of measurement, out of a set of conditions that includes the **same** measurement procedure, **same** operators, **same** measuring system, **same** operating conditions and **same** location, and replicate measurements on the **same or similar** objects **over a short period of time**

# Basic ... - Definitions in the VIM

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## 2.25 measurement reproducibility

reproducibility

measurement precision **under reproducibility conditions** of measurement

## 2.24 reproducibility condition of measurement

reproducibility condition

condition of measurement, out of a set of conditions that includes **different** locations, operators, measuring systems, and replicate measurements on the same or similar objects

NOTE 1 The different measuring systems **may use different measurement procedures**.

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# Basic principles ... - Bayesian statistic

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## Conventional statistic

The value of the **measurand** is assumed to be **an unknown constant** and the **measurement data are random variables**.

## Bayesian statistic

The **measurement data are constants** and the **value of the measurand is a random variable**. The probability distribution for the value of the measurand describes the **degree of belief about all possible values** that could be attributed to the value of the measurand.



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# Basic ... - Probability density functions (PDF)

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## conventional statistic

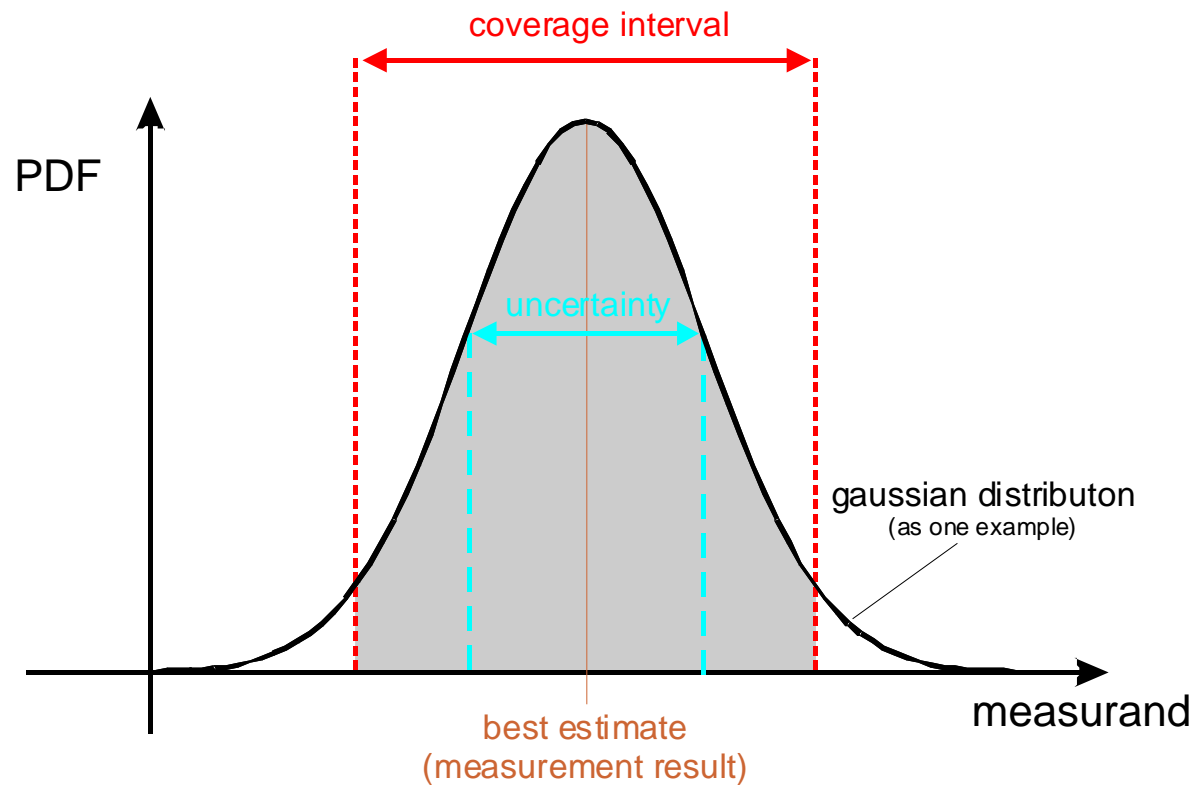
probability is understood to be the **relative frequency of the occurrence** of an observable random event in an infinite series of trials performed under identical conditions.

## Bayesian statistic

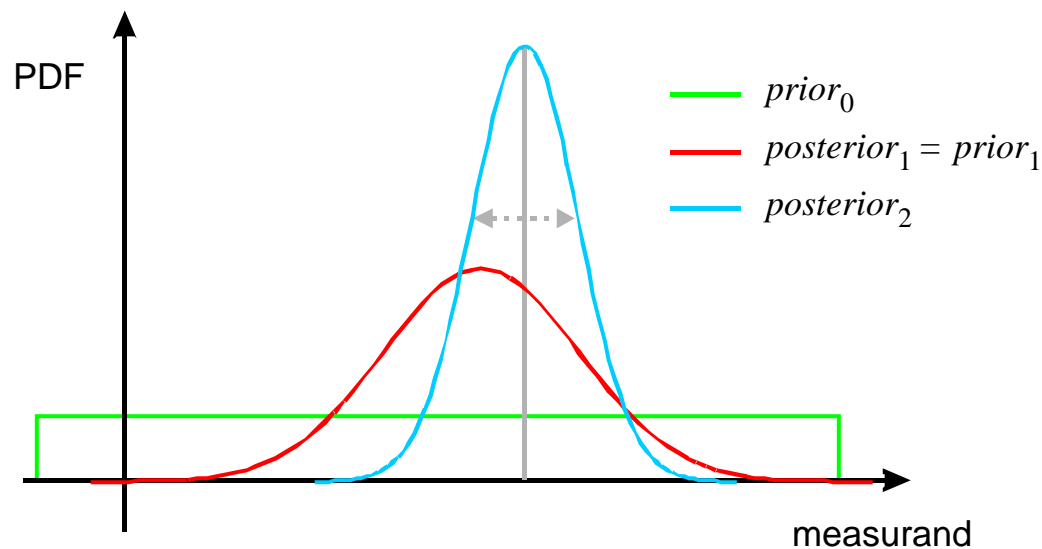
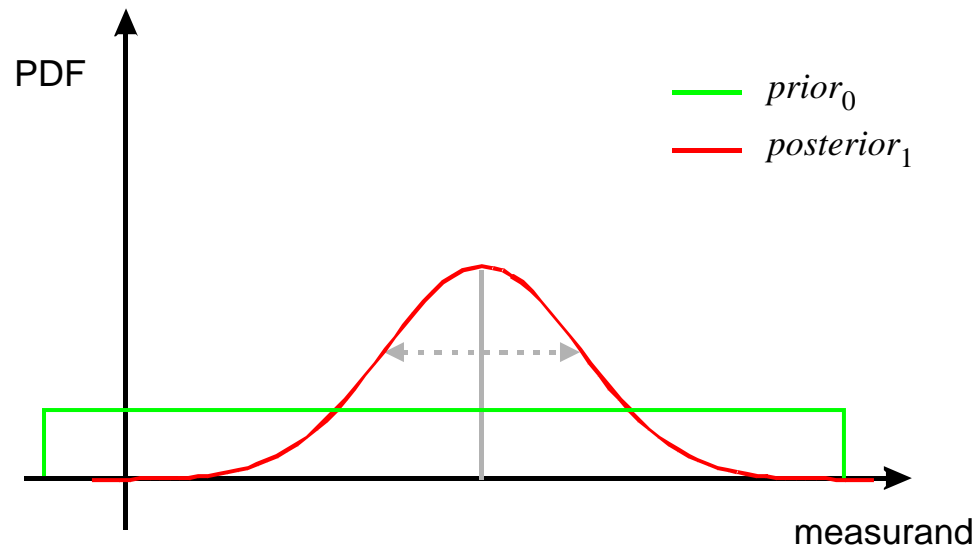
probability is understood to be a **degree of belief** or of the plausibility of a proposition, conditional on all relevant information that is available about that proposition.

# Basic ... - Probability density functions (PDF)

The probability density function describes the available knowledge about the quantity.



# Basic ... - Probability density functions (PDF)



more knowledge about the measurand

# Basic principles and background

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*Thank you for your attention*

*Questions ???*

[stephan.mieke@ptb.de](mailto:stephan.mieke@ptb.de)