

# Implementing Measurement Uncertainty in Analytical Chemistry

S Ellison

*The preparation of this paper was supported under contract with the Department of Trade and Industry as part of the National Measurement System Valid Analytical Measurement (VAM) Programme*



*Setting standards  
in analytical science*

# Introduction

- What is measurement uncertainty?
- Comparative approaches
- Relationship between MU and validation
- A way forward for chemistry

# What is Measurement Uncertainty?

“A parameter, associated with the result of a measurement, that characterises the dispersion of the values that could reasonably be attributed to the measurand”

*(ISO Guide)*

The number after the  $\pm$

# Uncertainty evolution

Pre-  
1978

Random/systematic error; Error propagation in chemistry (Eckschlager 1961); Collaborative study

---

1978-80

- BIPM INC-1 (1980)
  - Type A / Type B
  - Combine as variances

1982

- AOAC Stats manual (*Development/validation*)
- ISO 5725:1986 (*Collab trial*)

1986

1993

- **ISO Guide**

1995

- EURACHEM Guide 1st ed

1997

- 2nd EURACHEM workshop

- ISO 5725:1994 (*Adds trueness*)

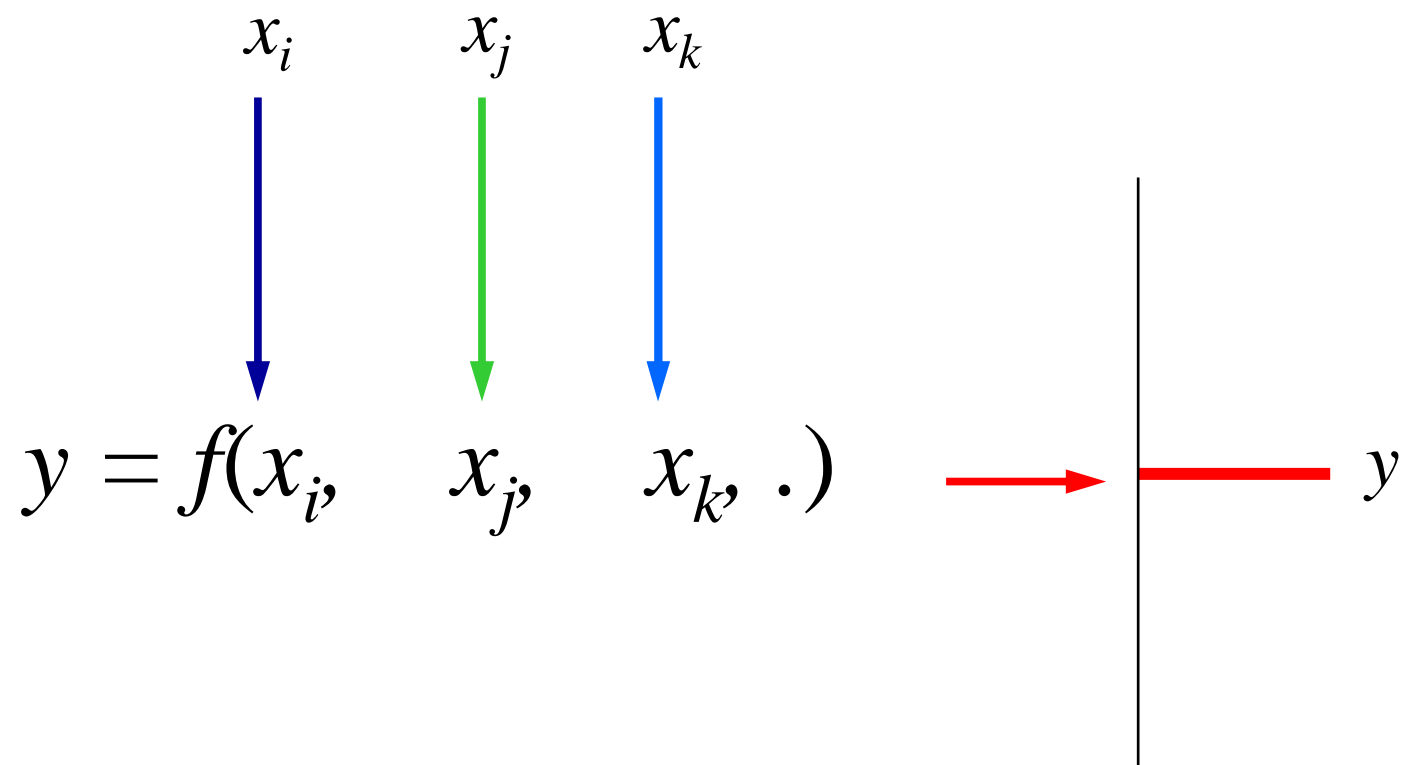
2000

- **New EURACHEM guide**



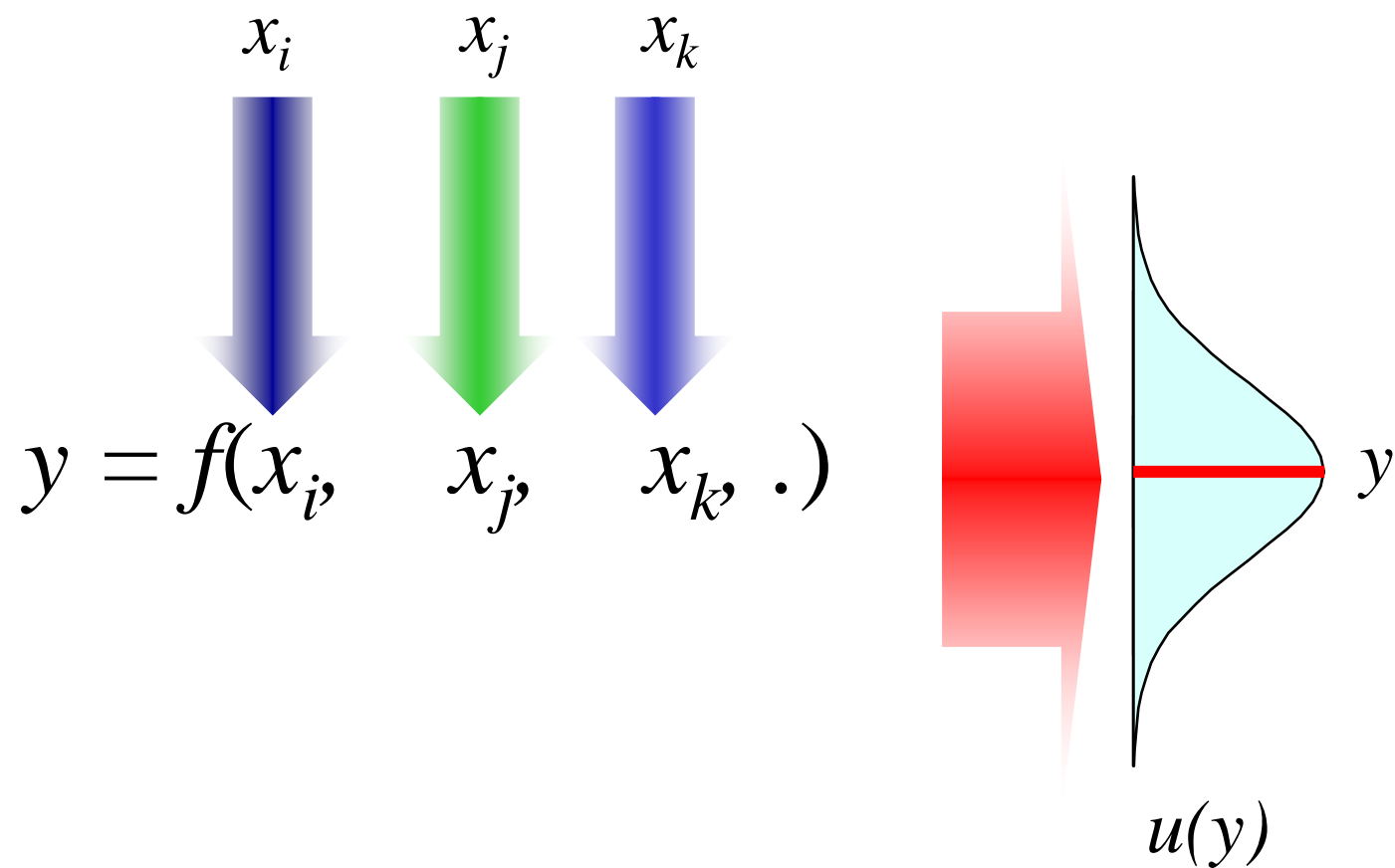
*Setting standards  
in analytical science*

# Models and Uncertainty



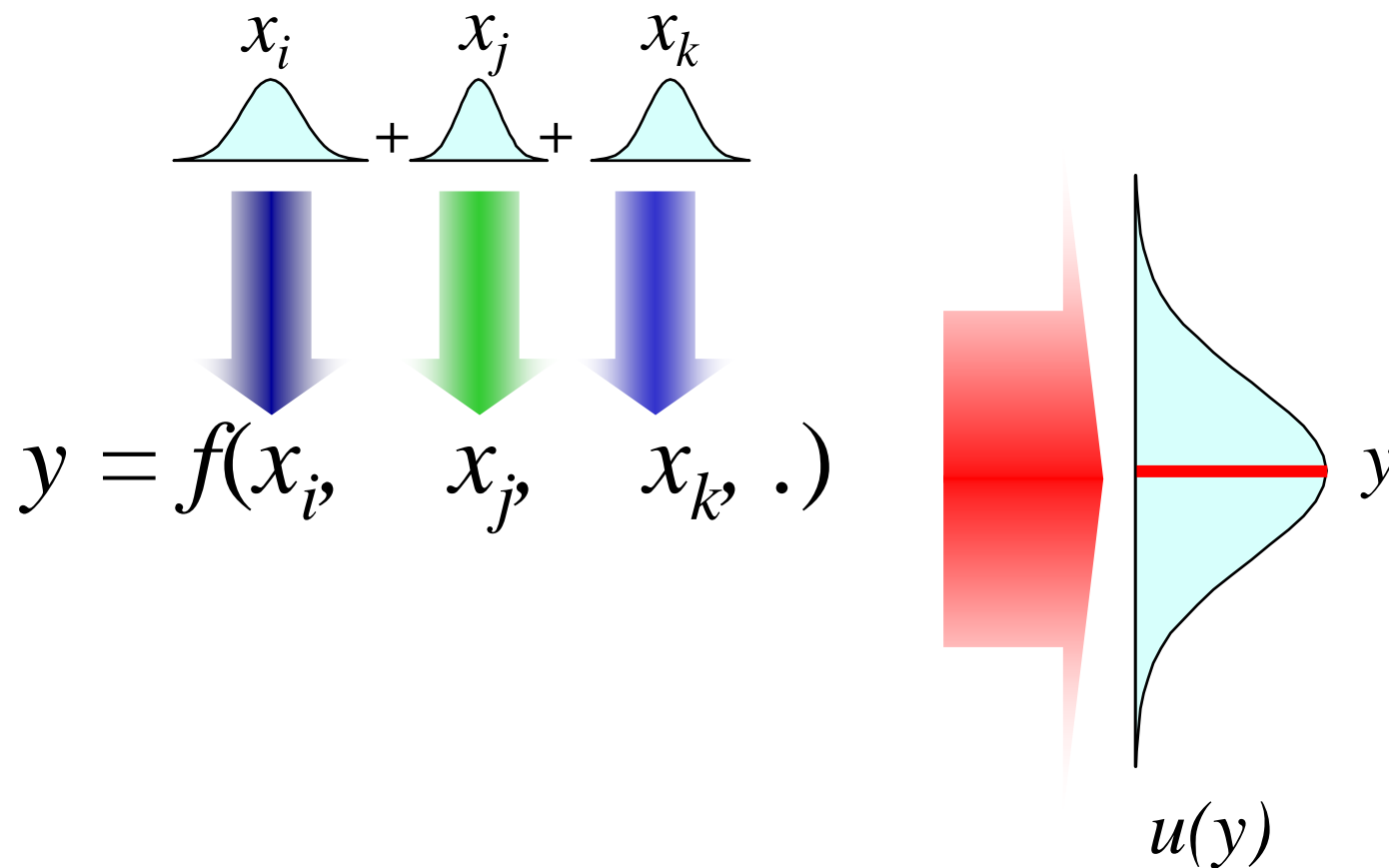
*Setting standards  
in analytical science*

# Models and Uncertainty



Setting standards  
in analytical science

# Models and Uncertainty



Setting standards  
in analytical science

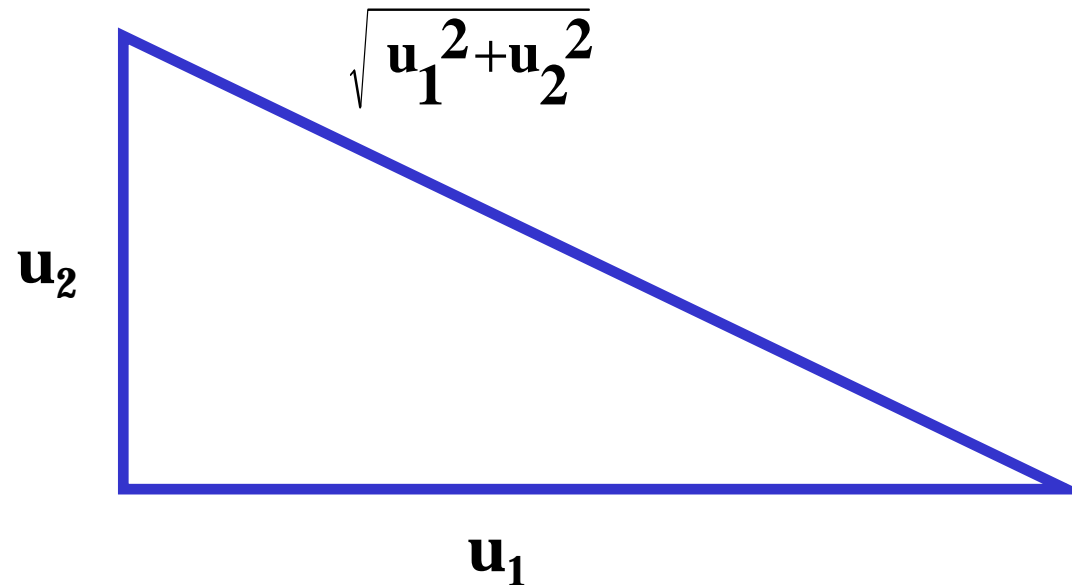
# ISO Guide approach

- Specify the measurand
  - including complete equation
- Quantify significant uncertainties in all parameters
  - A: from statistics of repeated experiment
  - B: by any other means (theory, certificates, judgement...)
- Express as standard deviation
- Combine according to stated principles



*Setting standards  
in analytical science*

# Combining uncertainties (ISO)

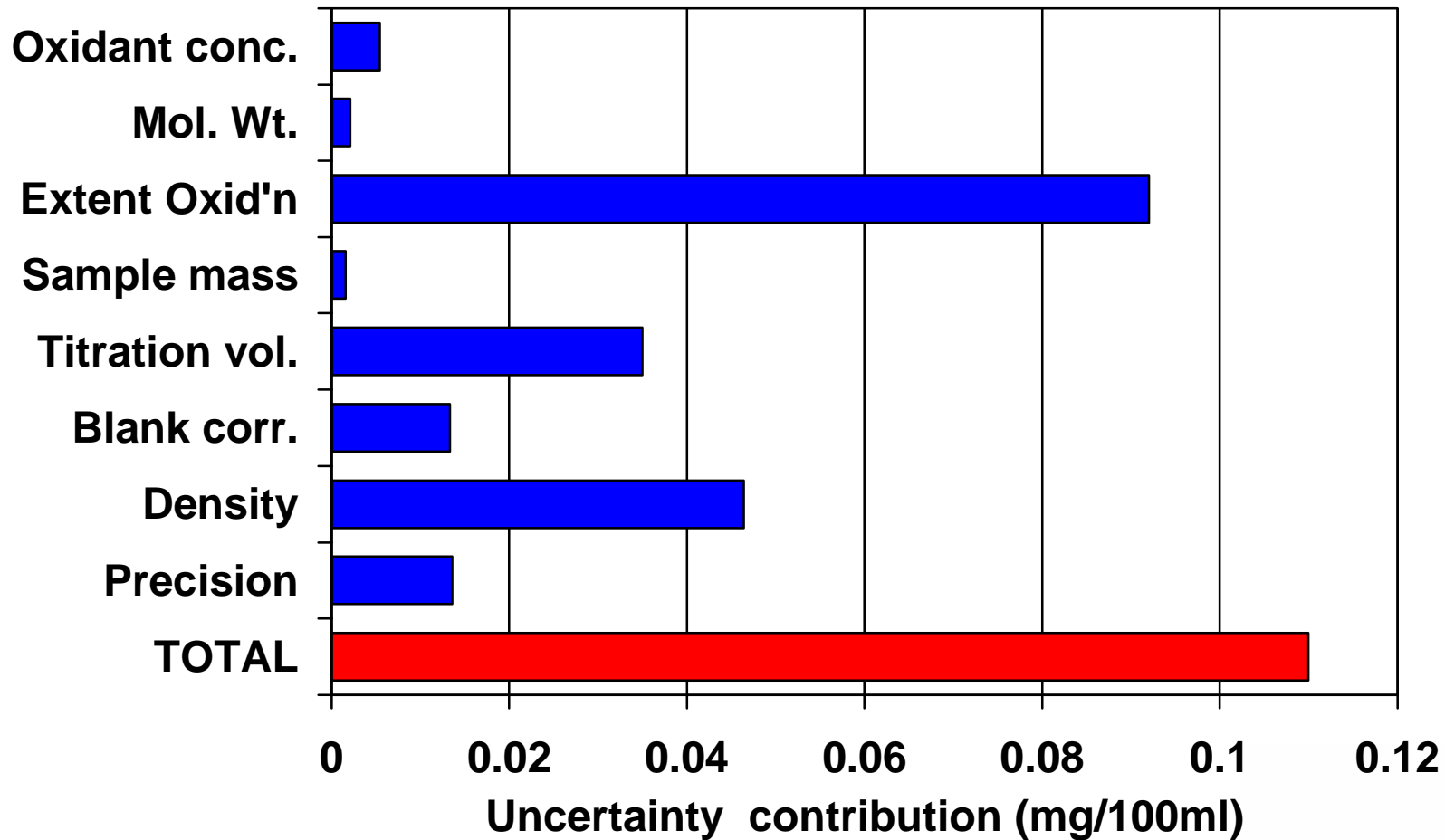


- *Standard deviations*
- *Established error propagation theory*



*Setting standards  
in analytical science*

# Example: Forensic alcohol standard titration



*Setting standards  
in analytical science*

# Implementing ISO in Chemistry

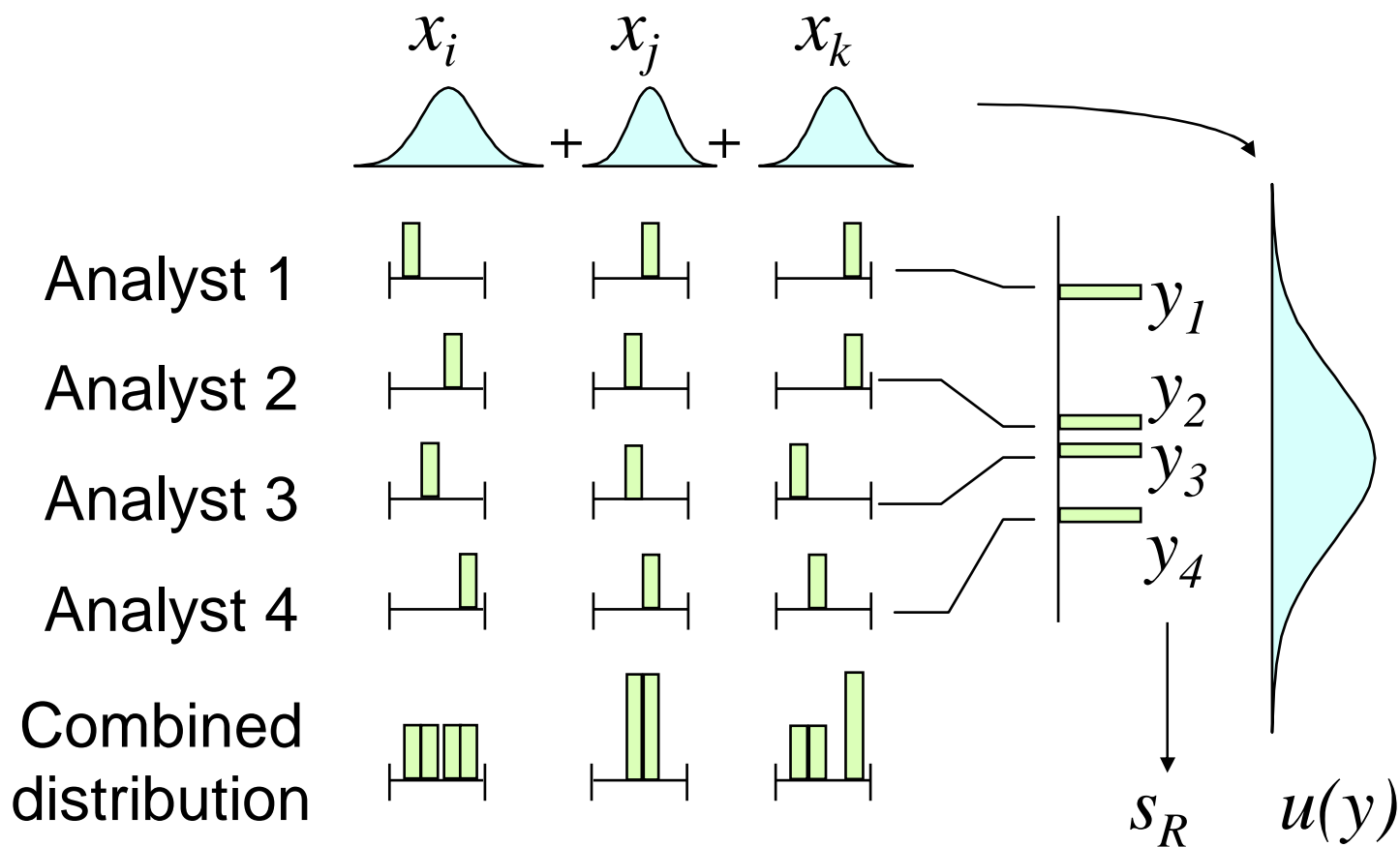
## Building models

- Every determinand is unique
  - Every element, every molecule, every formulation
- Every 'matrix' is unique
  - Different interactions with substrate
- Interactions with environment and substrate rarely understood
- **Models are difficult to build!**



*Setting standards  
in analytical science*

# Two views of influence factors



—|—| Nominal range      | Values



Setting standards  
in analytical science

# Real World problems

**“Well characterised”**  
quantified effects,  
differentiable, continuous,  
traceable

**Poorly characterised;**  
Unpredictable effects;  
Input parameters unclear



**WELL** ← Measurement model applies → **POORLY**

**POORLY** ← Whole method study applies → **WELL**

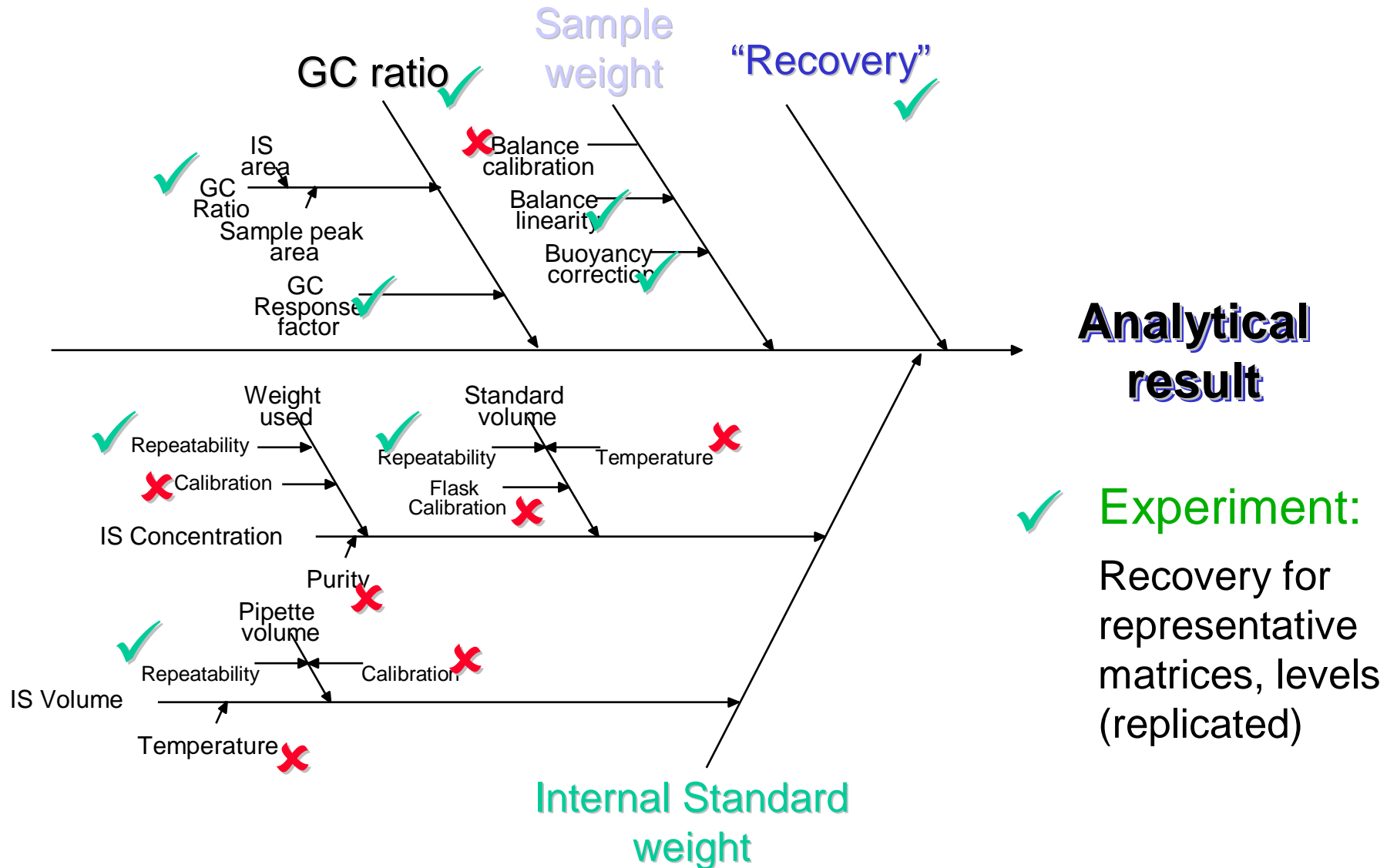


*Setting standards  
in analytical science*

# A Strategy for using validation data

- Develop list from main parameters and analyse their contributors
- Re-arrange to remove duplication, clarify contributions and group related causes
- Use the resulting structured list to plan experiments  
*IN THE LIGHT OF AVAILABLE INFORMATION*

# Validation experiment coverage



# A simpler model

- The best available estimate of precision
  - *An effect varied representatively during a precision experiment requires no further study*
- The best available estimate of bias *and its uncertainty*
- Other significant effects evaluated
  - By experiment, or from standing data



*Setting standards  
in analytical science*

# Real situations

- Collaboratively trialled method
  - Verified bias and precision in house
  - Main effects studied by developers
- In-house validation studies
  - Precision, bias, major effects
- Ad-hoc methods
- “Empirical methods”

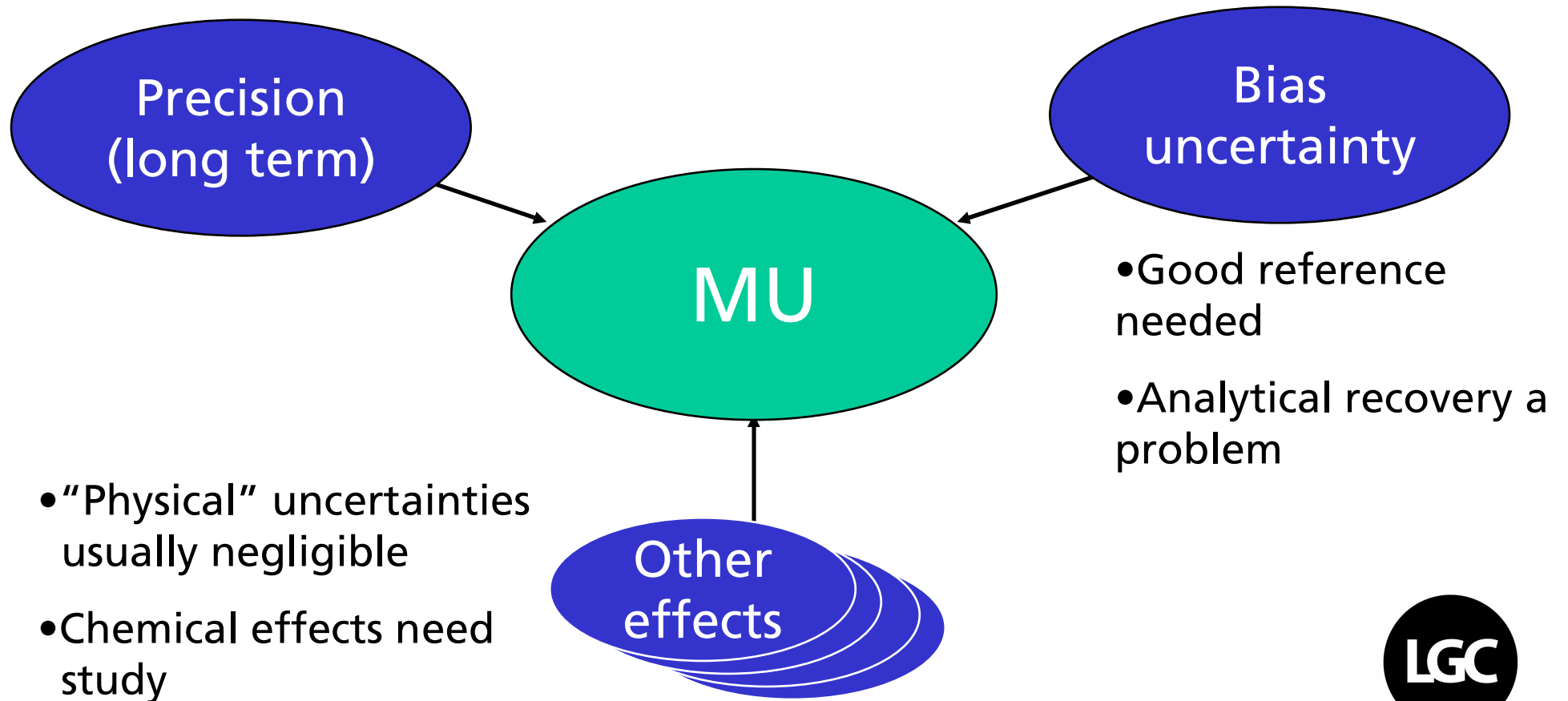


*Setting standards  
in analytical science*

# In-house validation

- Overall bias measured on RM
  - Insignificant or quantified
- Intermediate precision
  - Long term, multiple analyst/equipment
- Matrix and concentration effects studied
- Other significant effects identified and eliminated OR quantified

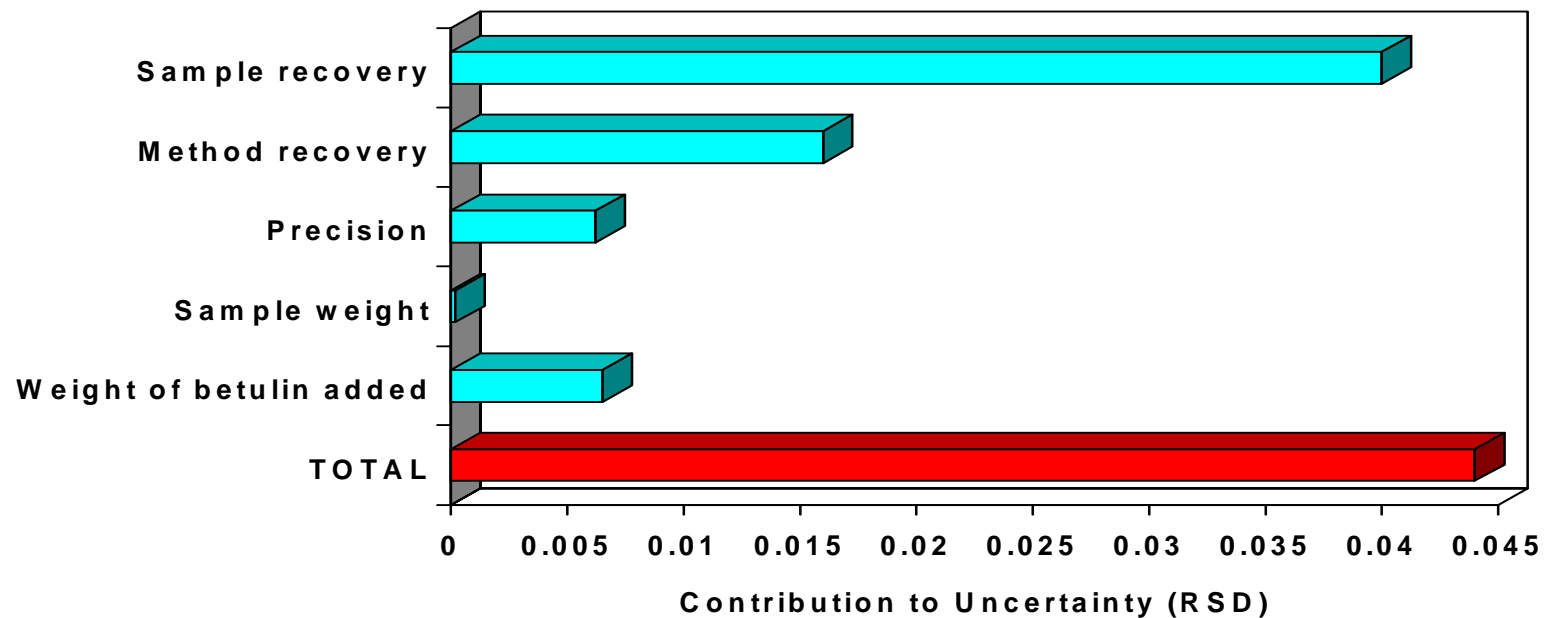
# In-house validation



*Setting standards  
in analytical science*

# Uncertainty Components

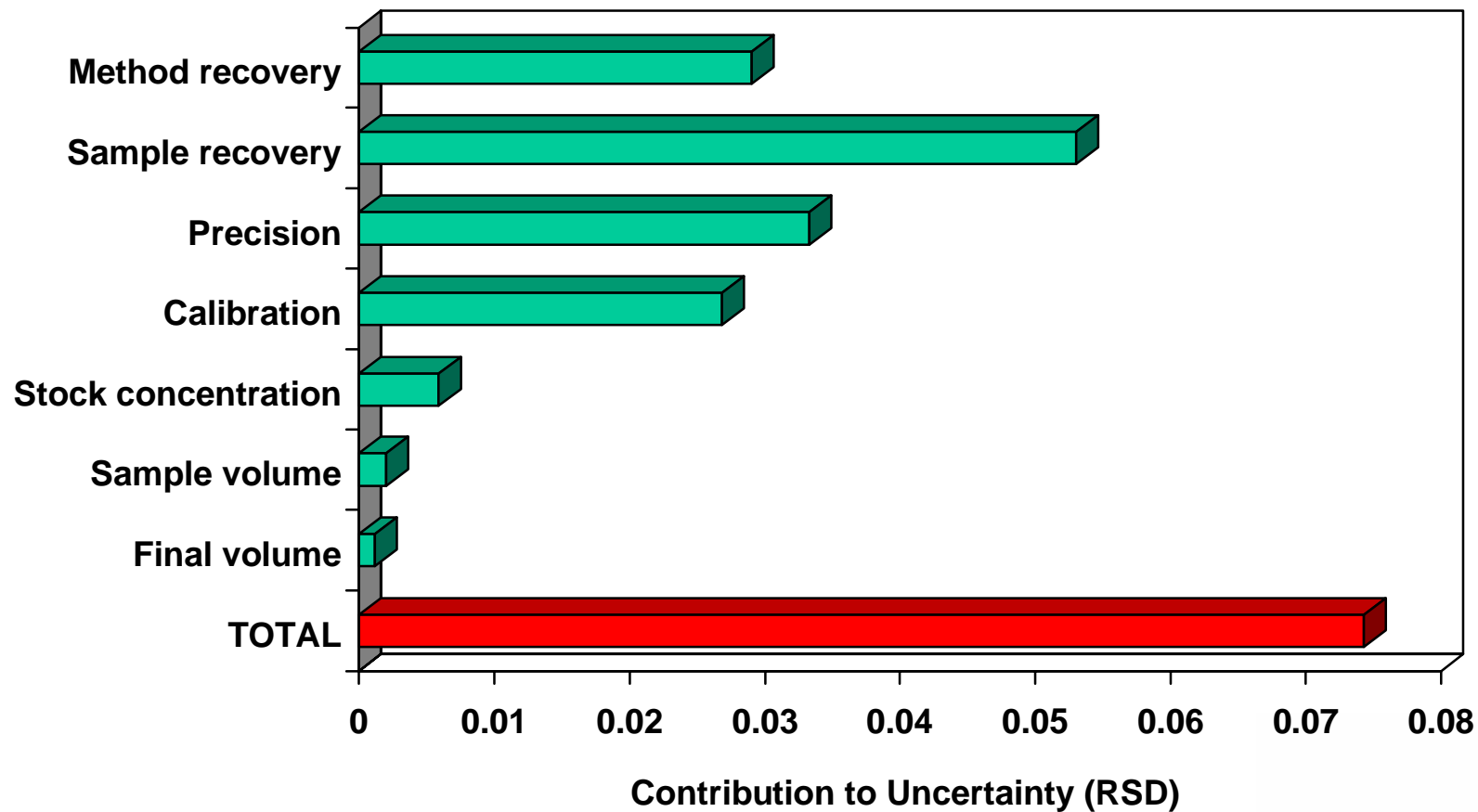
## Determination of Cholesterol



*Setting standards  
in analytical science*

# Uncertainty Components

## Determination of Acesulfam-K



*Setting standards  
in analytical science*

# Eurachem-CITAC Guide: A way forward

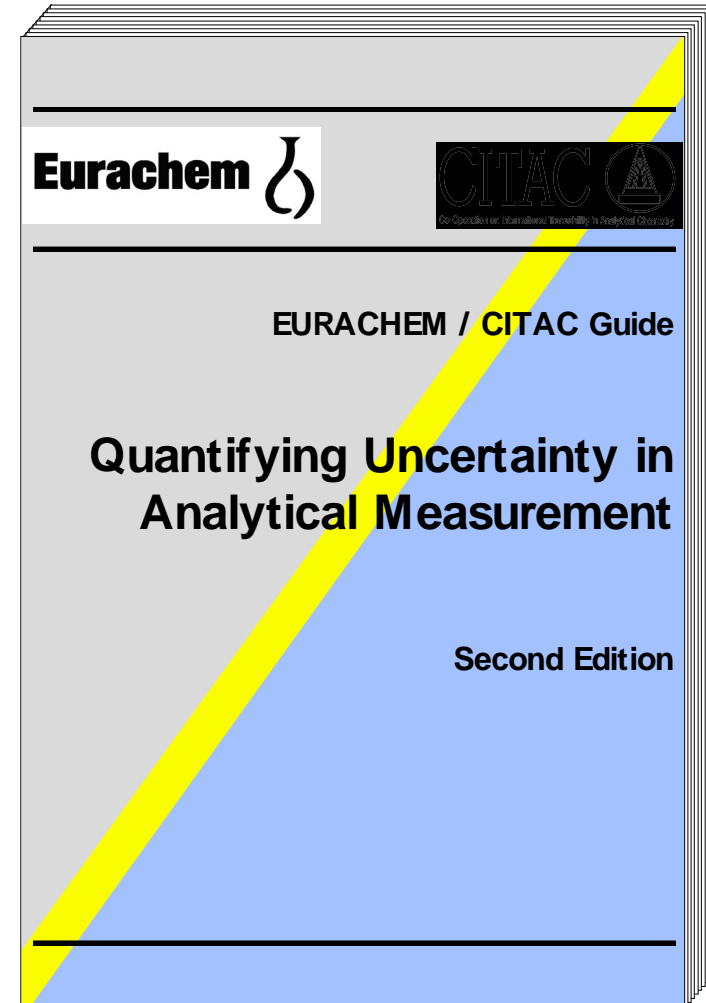
- Use ISO 'GUM' approach where applicable
- Use basic ISO 'GUM' principles to apply validation data
  - Allows quantitative uncertainty statements based on validation data
- Plan validation to give adequate information
  - Ensure that all significant factors are adequately covered
- Use both together to drive long term improvement



*Setting standards  
in analytical science*

# Conclusions

- MU arises from effects on the measurement process
- Validation and measurement uncertainty are views of the same problem
- EURACHEM-CITAC guide is the only MU guide explicitly using validation data!



<http://www.eurachem.bam.de/>