METAS in 2024

METAS
Your reference.

Cover picture: alkali vapour cell (blue tube) for atoms in Rydberg states with visible laser beams (see article on pages 16 and 17).

Legal notice

This report provides an overview of the activities of METAS in 2024.

Previous METAS annual reports

Objectivity
METAS works independently of specific manufacturers, brands and products. Illustrations and references in which manufacturers, brands or products can be identified do not constitute a recommendation by METAS.

Finances
Pages 30 and 31 of this report contain information on the annual financial statements of METAS as at 31 December 2024. The 2024 annual accounts have been published together with the auditor's report at www.metas.ch.

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Editorial

Milestones and visions: METAS in 2024

The year 2024 was full of significant events, developments and successes for METAS.

One important milestone to kick off the year was the appointment of Dr René Lenggenhager as the new President of the Institute Council from 1 January 2024. METAS also had the pleasure of welcoming two new members to the Institute Council, whose fresh perspectives and valuable ideas enrich our work (see page 5, "Foreword by the Institute Council").

METAS has actively followed its niche and excellence policy and developed it further. The intensified cooperation with universities and the clear increase in the number of doctoral students at METAS from one to five (see pages 8 and 9, "METAS in figures") are particularly pleasing. These collaborations are an essential component of our strategy to boost the scientific excellence and innovative capacity of our institute.

METAS also demonstrates its strong commitment to future technologies in projects such as "OnMicro" and "QUSPR", which involves the measurement of electric fields using Rydberg atoms (see pages 16 and 17, "Fundamentals and new technologies").

Other key figures for the institute (see pages 8 and 9, "METAS in figures") that showed a pleasingly positive trend in the reporting year include, for example, our higher level of self-financing (+1.4 %), the substantial increase in scientific publications (+35), the growth in Calibration and Measurement Capabilities (+25) and the fact that METAS had significantly more ongoing projects in-house (+22).

Finally, I would like to thank all our valued customers for their trust and long-standing loyalty. On the occasion of the 150th anniversary of the signing of the Metre Convention, METAS is inviting its customers to take an exclusive look at our work on the METAS open day in May 2025.

I would also like to acknowledge the far-sighted leadership of our Institute Council and the tireless dedication of our workforce. Together, METAS has achieved a great deal and can look to the future with confidence!

Dr Philippe Richard
Director of the Federal Institute of Metrology METAS

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Opening remarks

Thank you for the trust you have placed in us

From my office in the Federal Palace's West Wing to METAS in Wabern, Google Maps suggests a nice 3.8-kilometre walk, which also takes me along the River Aare. But is it really 3.8 kilometres, or 50 metres more? I don't need to know that exactly. This nonchalance in everyday life is liberating for citizens. In many situations, however, the utmost precision is required.

As engineers, physicists, chemists, and specialists of all kinds, the employees at METAS are architects of trust. Whether we are weighing bananas at a supermarket, filling up at a petrol station or breathing in the air, we trust that we will not be deceived, because METAS verifies instruments and performs checks.

METAS plays a key role in everyday life and yet often remains invisible. If things go wrong, however, it is sure to make the headlines. Consider, for example, the speed measurements in the city of Bern, when innocent citizens received a fine in error. Fortunately, however, the annual focus of checks is also covered by the media, such as spot checks on online shops or weight checks of bread on sale.

Thank you employees of METAS for the important work you did for Switzerland in 2024. I and all the residents of Switzerland are counting on you to continue to build trust with your undisputed expertise.

Beat Jans
Head of the Federal Department of Justice and Police

The Institute Council (from left): Dr Jonas Richiardi, Prof. Dr Sonia Isabelle Seneviratne, Roger Siegenthaler, Prof. Dr Alessandra Curioni-Fontecedro, Dr René Lenggenhager (President), Dr Ursula Widmer (Vice President), Dr Corinne Jud.

Foreword

Innovation and collaboration: our path to the future

2024 was characterised by profound changes in key technology areas: artificial intelligence, quantum technologies, cybersecurity, alternative energy sources, digital metrology and environmental protection are just some of the key issues that influence our work. The Federal Institute of Metrology METAS is facing the challenge of adapting its activities to these new trends in order to fulfil its overall mandate. Our employees are required to get involved in these areas and to contribute their expertise where and insofar as this makes sense and is necessary.

Despite these dynamic developments, METAS was able to continue its tradition of excellence. The active and competent commitment and valuable ideas of the two new Institute Council members, Dr Corinne Jud and Dr Jonas Richiardi, are particularly gratifying. Our Institute Council is diverse and broad-based, which is reflected in the variety of its expertise and perspectives.

My enthusiasm for METAS has grown even further as a result of numerous laboratory visits and discussions with employees. These meetings, including outside the Institute Council meetings, have made clear to me in impressive fashion the passion and professionalism with which our institute works.

The implementation of our strategy and the associated new structure of METAS have been further consolidated and optimised in the past year. Various process improvements have been initiated and some have already been put in place. Nevertheless, much remains to be done to further enhance operational excellence. Here, too, everyone is required to cooperate.

Another milestone was starting work on our new 2030 Strategy. METAS is driving this process forward with a great deal of creativity and with a workshop involving the entire Institute Council and the Executive Board, as well as the support of a "steering group". New development tools are helping us to devise a forward-looking strategy, which can then be submitted to the Institute Council for approval.

A particular highlight of my first year as President was undoubtedly the visit of Federal Councillor Beat Jans, the new Head of the Federal Department of Justice and Police (FDJP), in March 2024. METAS was proud to present our best small national metrology institute to him (see also Mr Jans' opening remarks on the left).

In conclusion, I would like to emphasise how happy I am to be involved with METAS. I am proud to have the chance to lead a strong and committed Executive Board as well as an expert and active Institute Council and would like to take this opportunity to thank all employees for their dedicated contribution last year and this year.

Dr René Lenggenhager
President of the Institute Council

Highlights of 2024

In the past year, METAS once again celebrated a number of highlights – and not just those of a scientific or metrological nature. A general highlight was undoubtedly the visit of Federal Councillor Beat Jans (FDJP) to METAS.

1 January 2024

Analytical method for new heating oil fiscal marker
On behalf of the Federal Office for Customs and Border Security (FOCBS), the chemical tests and consultancy technical field at METAS (CPB) has developed and introduced an analytical method for a new fiscal marker. The fiscal marker is added to heating oil to distinguish it from diesel fuel. Switzerland has joined forces with the EU to introduce this new, more reliable fiscal marker, as the previous one had become increasingly vulnerable to counterfeiting.

25 March 2024

Visit of Federal Councillor Beat Jans (FDJP)
During his visit to METAS, the new Head of the FDJP, Federal Councillor Beat Jans, was given an introduction to the diverse activities of the institute and then visited various laboratories. At the end of his visit, the Department Head gave a welcome address for all METAS employees and was able to engage in dialogue with a few attendees.

25 May 2024

Dr Guglielmo Frigo receives “Best Paper Award IEEE SGSMA 2024”
At the Smart Grid Synchronized Measurements and Analytics Conference (SGSMA) of the Institute of Electrical and Electronics Engineers (IEEE) in Washington D.C. (USA), Dr Guglielmo Frigo, scientist in the Electrical Energy and Power Laboratory at METAS, was presented with the Best Paper Award 2024. Dr Frigo investigated the frequency measurements to improve the resilience and reliability of power systems as part of the “QUINPORTION” Swiss Federal Office of Energy project.

25 June 2024

First nanoparticle measuring instrument course
In summer 2024, the first nanoparticle measuring instrument course took place at METAS. During the course, participants are given an overview of the legal aspects of diesel particulate filter testing (DPF), learn the fundamentals of metrology and aerosols, and get to know the practical challenges. The course is primarily aimed at vehicle experts from the driver and vehicle licensing offices and garage operators.

Nanoparticle measuring instrument course at metas.ch

13 November 2024

Strategic goals for 2025 to 2028
On 13 November 2024, the Federal Council approved the strategic goals for METAS in 2025 to 2028. These state that METAS is primarily to continue to perform its tasks as Switzerland’s national metrology institute. In the future, it is to digitalise metrological services as far as possible or advance their development for digitalisation and coordinate the quality infrastructure in Switzerland.

29 November 2024

Dr Cédric Blaser receives “IEC 1906 Award”
At the board meeting of the Comité Électrotechnique Suisse (CES), the IEC 1906 Award was presented to Dr Cédric Blaser, Head of the Electrical Energy and Power Laboratory at METAS. Dr Blaser was honoured for his work on standardising electricity meters and his involvement in the creation and revision of more than ten standards at European and international level.

31 December 2024

Gas monitoring in industrial production environments
The gas analysis laboratory conducted around 30 calibrations of diode laser spectrometers for in-situ gas monitoring in industrial production environments using a new measuring station specially developed for Mettler Toledo. The flexibility of this measuring station also made it possible to implement tailor-made R&D orders for our customer.

Implementation of the Metrology Act

METAS ensures compliance with metrology law in Switzerland.

Tests by METAS

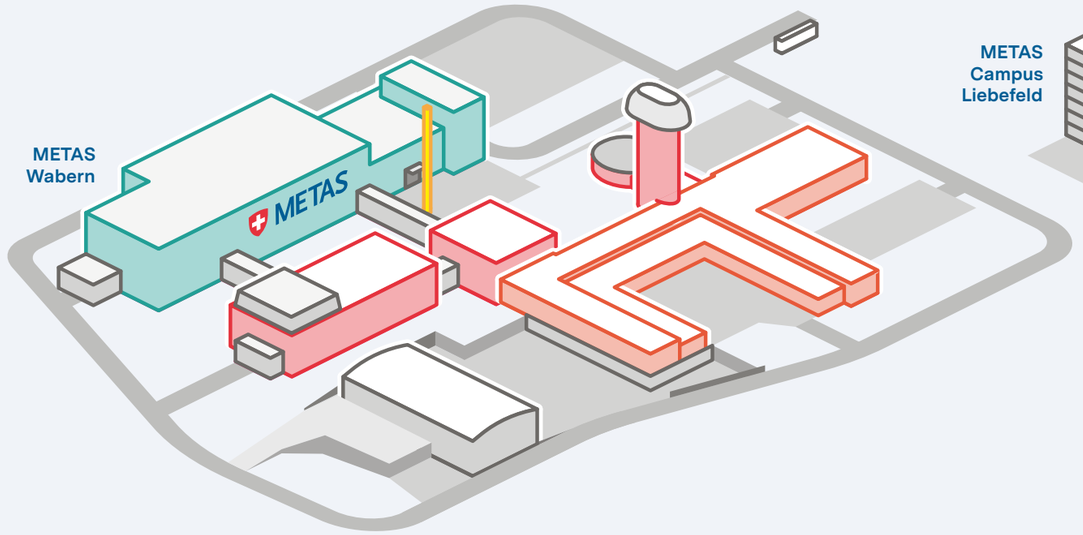
47,445 instrument transformers (initial verifications)
3,351 breath alcohol analysers
2,573 road traffic measuring instruments (red light and speed)
1,947 audiometry measuring instruments
763 measuring instruments for nanoparticles in combustion engines
550 sound measuring instruments
248 flue gas measuring instruments (initial verifications)
210 measuring instruments for ionising radiation

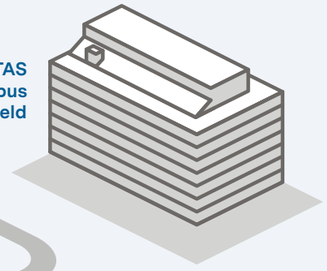
Tests by authorised verification laboratories

741,735 electricity meters (statistical test procedure)
7,299 measuring instruments for thermal energy
3,394 flue gas measuring instruments
2,232 measuring instruments for ionising radiation
484 road traffic measuring instruments (HGVC test systems)
429 measuring instruments for gas quantity

Tests by the cantons

97 % implementation rate for verification of measuring instruments
88 % implementation rate of tested pre-packaged goods of the same nominal quantity, industrial manufacturers
86 % implementation rate of tested pre-packaged goods of a different nominal quantity, industrial manufacturers





METAS in figures

Last updated on 31 December 2024

CMCs

419 measurement and calibration options recognised under the CIPM-MRA

Certificates issued by METAS

17,482 (of which: 446 by METAS-Cert)

Organisations

15 metrological laboratories

5 in the Metrology in Physics I sector:
DC and Low Frequency | Electrical Energy and Power | High Frequency | Electromagnetic Compatibility | Photonics, Time and Frequency

5 in the Metrology in Physics II sector:
Length, Nano- and Microtechnology | Optics | Mass, Force, Pressure and Vibration | Flow | Ionising Radiation

5 in the Metrology in Chemistry and Biology sector:
Gas Analysis | Particles and Aerosols | Inorganic Analysis and References | Organic Analysis and References | Biological Analysis and References

3 technical divisions

Verification and testing:
Traffic | Acoustics and Vibration | Audiometry

Chemical tests and consultancy:
Analysis | Tests and Consultancy

Measurement networks:
Quality and Maintenance | Intervention and Installation | Software

Research and development

88 scientific publications

60 lectures **14** seminars

5 specialist conferences

28,591 hours invested in research

2 new patents pending
1 patent was discontinued.

7 patents pending in the portfolio in total

6 invention reports

Projects

Large-scale projects (LP) and small-scale projects (SP)

65 ongoing (47 LP + 18 SP)
25 restarted (20 LP + 5 SP)
21 concluded (10 LP + 11 SP)

47 large-scale research projects funded
(21 EPM, 6 EMPIR, 5 METAS, 5 Federal Policy Research, 3 Horizon Europe, 3 Innosuisse, 2 Swiss National Science Foundation, 2 contract research)

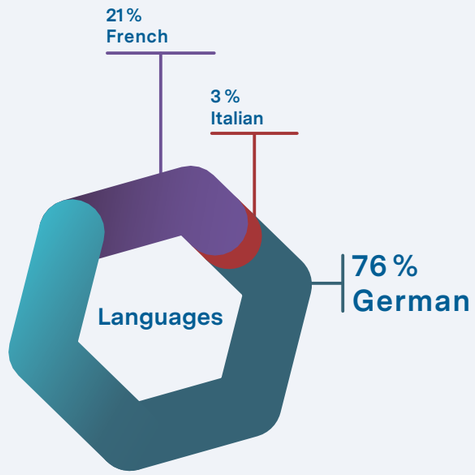
Finances

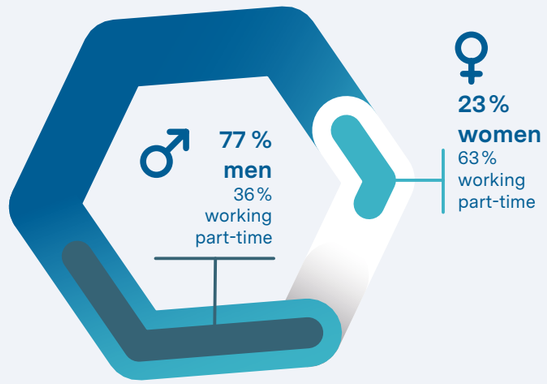
CHF 61 m
revenue

CHF 921,000
profit

58 %
level of self-financing

Employees





Apprentices

Physics laboratory technician
Chemical laboratory technician
Electronics technician
Computer scientist
IT specialist
Mediamatics technician
Business management internships for the commercial employee apprenticeship

19
trainees
and BM interns

5 doctoral students

9
academic interns

250
employees

Research and development

Research through collaboration

Research is essential for the further development of Switzerland's metrological infrastructure. Thanks to successful cooperation and the acquisition of third-party funding, progress was made in new topics such as quantum technology. In addition, METAS got involved in the training of young scientists and stepped up its measures to promote scientific integrity.

Research as a mandate

METAS is at the top of the metrological pyramid, meaning that it provides internationally recognised units of measurement with the accuracy required for industry, research and administration. As accuracy requirements are increasing across the board – especially on the part of customers – METAS must ensure that its reference standards are always more accurate than those of customers. Art. 3, para. 2, let. d. of the Federal Act on the Federal Institute of Metrology (EIMG, SR 941.27) also stipulates that the "necessary scientific and technical investigations and development work" must be carried out. Accordingly, METAS is to research "specifically the effects of new techniques" and develop "practically applicable measuring methods" that "correspond to the state of scientific knowledge".

METAS finances internal research projects and also strives for research financed by third-party funding, in particular through the European Partnership on Metrology (EPM). Other sources of funding include the Swiss National Science Foundation, the Swiss Innovation Agency (Innosuisse), federal policy research and contract research from industry.

EPM projects not only contribute to the financing of METAS projects, they also promote collaboration between experts from various European metrology institutes. The call for proposals for EPM projects takes place in two stages: research topics can be submitted in January and February, of which more than half are selected. Research consortia are then formed, which submit their applications by the end of September. Independent expert assessors decide on funding in November, with a relatively high success rate compared to other programmes (typically 50 %). The projects usually last three years.

As Switzerland is not yet associated with Horizon Europe, funding is provided by the State Secretariat for Education, Research and Innovation (SERI). METAS was very successful in the 2023 call: eleven project proposals were approved, including four in the field of quantum technology. These projects started in June 2024 and will further expand METAS' expertise in this area. In addition to the EPM projects, two new Horizon Europe projects, two innosuisse projects and three federal policy projects began in 2024. As a result, all of the five topics are being addressed with new projects.

Federal Act on the Federal Institute of Metrology (EIMG, SR 941.27)

Collaboration with universities

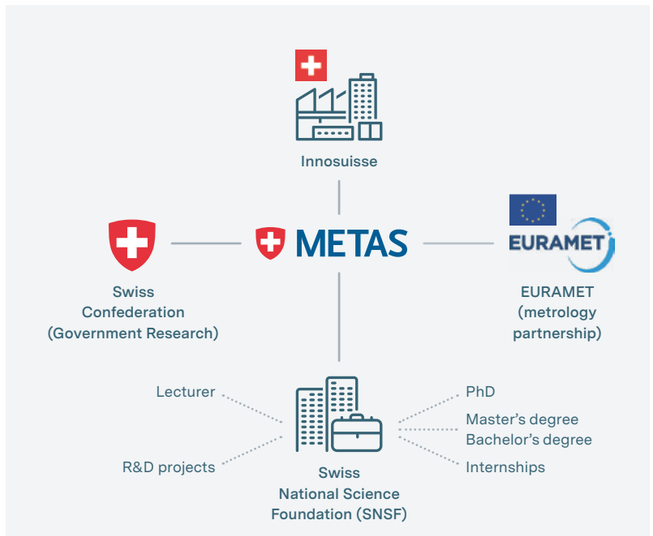
In most of its research projects, METAS works with national or international higher education institutions, as collaboration and dialogue between leading experts are key to success in research.

Apart from these research projects with universities, which are mostly financed by third-party funding, bachelor's, master's and doctoral theses can be completed in METAS laboratories. In 2024, for example, five doctoral students worked for METAS. These doctoral theses are supervised by professors from the higher education institutions as well as by a METAS scientist on site. Two doctoral students were enrolled at EPFL in Lausanne, two at the University of Bern and another at the University of Basel.

In some cases, METAS experts also work as lecturers at higher education institutions. In 2024, for example, METAS experts gave lectures at the Universities of Basel and Bern, at ETH Zurich and at the University of Applied Sciences and Arts Western Switzerland HES-SO.

This mutually stimulating cooperation between Swiss universities and METAS is to be further expanded in the coming years. This will integrate METAS even more closely into the Swiss higher education landscape and enable it to contribute to the scientific excellence of Switzerland as a centre of research.

The five research and development topics at METAS



Forms of national and international research cooperation.

Scientific integrity

For an institution like METAS, which creates trust and develops reliable references in its metrological work, acting with integrity is essential in all areas of activity. This also applies in particular to research.

But what are some examples of breaches of scientific integrity? The best known are falsification of data, failure to take co-authors into account, misconduct in expert reports, lack of support for academic associates and even plagiarism.

The four basic principles of reliability, honesty, respect and responsibility, on which scientific integrity is based, are already a firm fixture of METAS' culture. As a result, we are fortunately not currently aware of any such breaches. Nevertheless, based on the code of conduct for scientific integrity of the Swiss Academies of Arts and Sciences, METAS has made its scientists aware of this issue and created a point of contact for relevant questions.

Swiss Academies of Arts and Sciences: scientific integrity

Energy and mobility

Metrology for more reliable integration of renewable energies

Renewable energy sources generally generate direct current. Measuring and controlling them requires a new range of measuring applications.

The control and storage of renewable energy sources still rely on measuring applications that are neither standardised nor well established. METAS is working to support this energy transition by developing full metrological traceability for these operations – in the “DC Grids” project for revenue metering and power quality and in the “DigiCell” project for battery health.

Direct current revenue and power quality measurement in modern power supply systems

Medium- and low-voltage direct current microgrids are becoming increasingly important for the efficient integration of renewable energy sources, especially in scenarios where generation and consumption profiles can be planned with sufficient accuracy (e.g. car parks, airports, shopping centres). Nevertheless, disturbances caused by power electronic converters or connection to the alternating current grid remain a challenge. The existing measurement technology is primarily designed for traditional direct current networks in which the power signal is largely constant.

However, in the new scenario, direct current levels are subject to fluctuations depending on the availability of renewable energy, and unwanted signal components may also arise. The EPM project “DC Grids” (EPM = European Partnership on Metrology) addressed the problem of revenue measurement and grid quality monitoring in direct current microgrids. METAS led a work package and coordinated the development of reference systems that can simulate direct current signals under nominal and distorted conditions. These reference systems are used to evaluate different classes of measuring instruments, both for billing measurement and for grid quality analysis. This is a first step towards the precise definition of performance requirements and compatibility limits in direct current microgrids. Both aspects are essential to ensure stable and reliable operation of the power grid.

Uncertainty in battery measurements and AI

The state of health (SOH) of lithium ion batteries is an indicator of their capacity under nominal conditions. Capacity measurement by charging and discharging takes up time and energy. In conjunction with machine learning algorithms (ML, see box), electrochemical impedance analysis (EIS), which measures the reaction of a battery to electrical signals, is a fast, energy-saving method for measuring the SOH.

Dr Guglielmo Frigo at the final presentation in Delft (NL) on 16 May 2024.

Direct current power and energy reference system in the METAS laboratory.

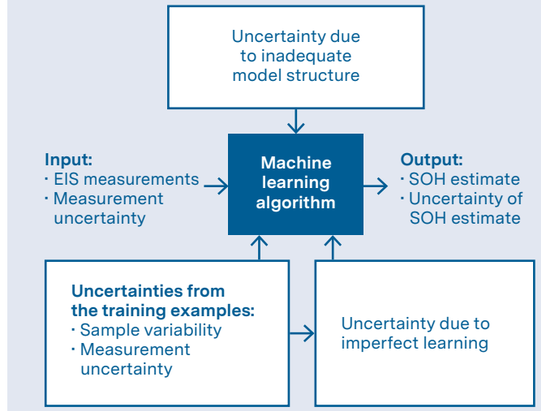
In the “DigiCell” project, METAS is developing a method for quantifying the uncertainty of predictions from ML models, which is applied to the SOH estimate.

ML algorithms are powerful, but susceptible to uncertainties arising from the data (measurement uncertainties, variability) and the models themselves. If these uncertainties are ignored, they can affect the reliability of the result, which in turn would have economic and environmental consequences. With this methodology, METAS aims to improve the reliability of the ML models and thus contribute to the optimisation of manufacturing processes and proactive maintenance of batteries.

Although the focus of this project is on lithium ion batteries, there is a much wider range of possible applications for the technique – the methodology developed can be applied to most of the problems in metrology where ML models are used, and thus offers solutions tailored to the needs of industry.

What is machine learning?

Machine learning (ML) is an artificial intelligence technique that enables computers to solve problems by analysing data without having been explicitly programmed to do so. By using (usually a large number of) examples, the system recognises patterns and makes predictions. For example, it can predict the state of health of a battery (SOH) based on complex measurements. This is a key technology for optimising industrial processes.



Overview of sources of uncertainty in the use of ML algorithms applied to battery characterisation.

Joint initiative on British-Swiss cooperation in metrology

In 2024, METAS intensified its cooperation with the British National Physical Laboratory (NPL) to exchange knowledge and make use of financing options under the new Memorandum of Understanding (MoU) between Switzerland and the United Kingdom. As part of this, METAS was visited by an NPL delegation, accompanied by Martina Novakova, head of Science and Innovation at the British Embassy in Bern.

British delegation at METAS (from left): Dr Deborah Ritzmann (NPL), Dr Peter Davis (NPL), Martina Novakova (Science and Innovation Officer of the British Embassy in Bern), Dr Guglielmo Frigo (METAS), Dr Marc-Olivier André (METAS).

Health and life sciences

Measurements for life: process contaminants, microflows and radionuclides

In 2024, METAS laboratories made lasting improvements to their measurement and production capabilities for food safety and medicine.

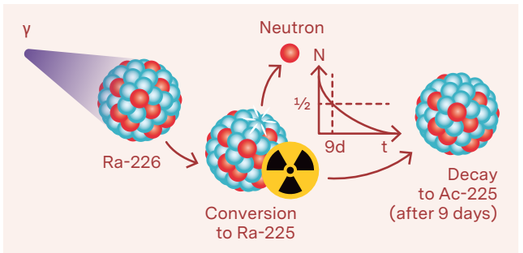
Health and life sciences have undergone significant further development at METAS in recent years. METAS expanded on the measurements of process contaminants in foodstuffs, the metrologically accurate description of microflows and the manufacture of therapeutic radionuclides for the treatment of tumours. In these three highly relevant areas, METAS makes a direct contribution to improving the quality of life in Switzerland.

Photonuclear reactions for theragnostics

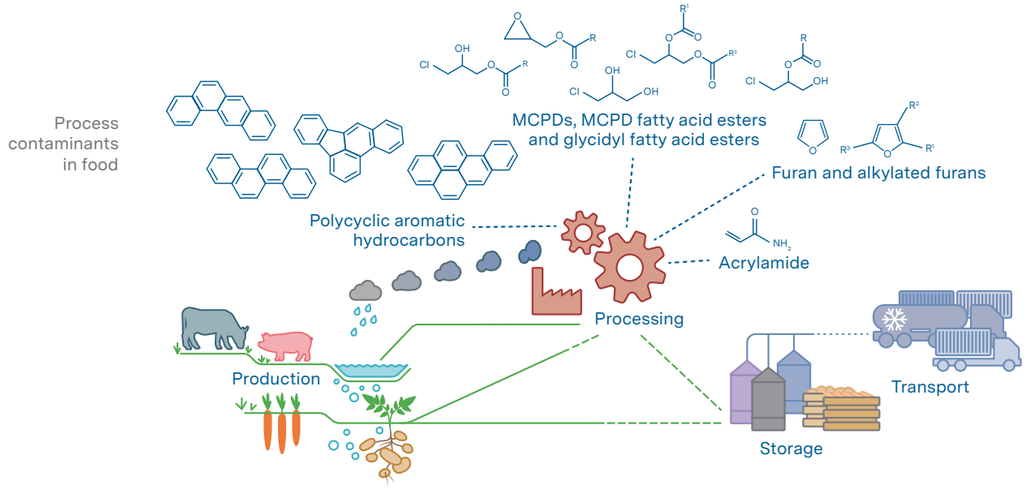
An innovative approach in cancer medicine combines radioactive elements with selective molecules to accurately label or destroy tumour tissue (therapy and diagnostics). Elements such as actinium-225 are used, but this is very scarce worldwide. In order to overcome this shortage, METAS has developed efficient production processes in collaboration with the University of Bern. Actinium-225 was produced synthetically using the photonuclear route, by irradiating radium-226 with high-energy X-rays. This method is easy to manage and uses electron accelerators like the one at METAS to generate the necessary X-rays.

METAS investigated this production route and developed it by irradiating over sixty samples with different basic materials. In order to boost the production rate, the accelerator was upgraded and a new method for accurately measuring production rates was established. For industrial use, the power of the electron accelerator has to be significantly increased again, which poses technical challenges for the generation of X-rays.

An innovative concept for coping with thermal stress was developed based on a pump principle by Nikola Tesla. A prototype was successfully tested and a patent was applied for. Initial steps have been taken to test more powerful accelerators.



If X-rays have sufficient energy, radium-226 is converted into radium-225, which then decomposes to the desired actinium-225.



Determining process contaminants in food

Process contaminants are undesirable substances that develop during the processing of foodstuffs, for example when heating them to high temperatures, refining, fermenting, smoking or drying them, and may have a negative impact on human health. The legally stipulated maximum levels for these substances in food must be checked with comparable analyses in Switzerland and the EU.

This is ensured by the network consisting of the European Union Reference Laboratory for Process Contaminants (EURL-PC) and the National Reference Laboratories (NRL PCs). As the NRL-PC in Switzerland, the Organic Analysis and References Laboratory at METAS thus functions as an interface between the official laboratories and the EURL-PC.

In addition to the existing methods for determining polycyclic aromatic hydrocarbons (PAHs), free monochloropropanediols (MCPDs) and those esterified with various fatty acids, and glycidyl fatty acid esters (GEs) in food, the range of methods at METAS has been expanded to include the determination of acrylamide as well as furan and alkylated furans in food. The comparability of the analysis results obtained with these methods was successfully demonstrated in several suitability tests organised by the EURL PC.

National Reference Laboratory for Process Contaminants

Calibration of liquid microflows in outstanding quality

METAS has equipment with piston systems (Fig. 1) and gravimetric flow measurement (Fig. 2) for measurements with process liquids and non-constant flow profiles. These characterisation measurements are typical for applications in the dosage of process liquids used in the pharmaceutical industry, in fluid chemistry and in microfluidic applications.

METAS is the world's leading National Metrology Institute in terms of experience and precision in the traceable calibration of microflow rates down to 20 nL/min. Any influences of environmental conditions and liquid properties were quantified and taken into account in the detailed calculation of the measurement uncertainty of the corresponding microflow rates. For this reason, METAS, as a pilot laboratory, organised the first international measurement comparison of six metrology institutes with these low liquid flows. This is registered with the International Bureau of Weights and Measures (BIPM) as CCM.FF-K1.2022. The specified measurement uncertainties in the flow range from 10.0 µL/min to 0.1 µL/min were successfully validated and confirm the excellent measurement capabilities of this equipment.

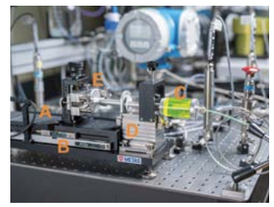


Fig. 1: METAS piston system of the microflow unit: (A) high-precision linear table, (B) linear measuring system, (C) piston, (D)+(E) piston mounting and positioning.

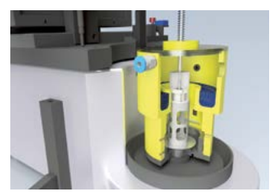


Fig. 2: Gravimetric flow measurement with a view of the weighing area of the balance with outlet needle and container.

Fundamentals and new technologies

Optical techniques for field measurements and time transmission

Laser technology enables electrical field measurements and time transmission through the White Rabbit protocol.

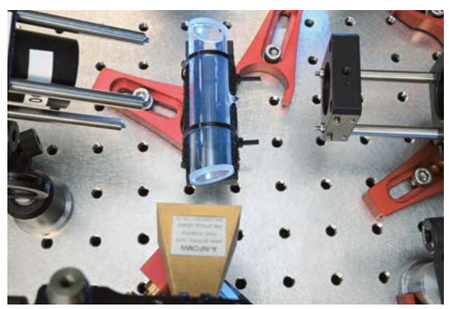
METAS applies laser spectroscopic techniques to use individual atoms, known as Rydberg atoms, for electrical field strength measurement. In addition, the White Rabbit protocol is transmitted using lasers and optical fibres, which enables high-precision time dissemination (time transmission) by METAS.

Quantum sensing with Rydberg atoms

Electric fields are an integral part of everyday life at METAS. For example, they are used to process information in computers or to transmit it with a mobile phone. To date, metal contacts or antennas have mainly been used to measure these fields. This has the disadvantage that the fields are distorted by the measurement, resulting in higher measurement uncertainties.

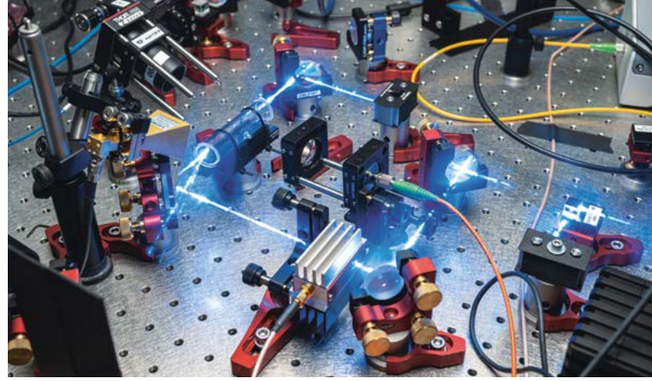
METAS is working on measuring electric fields using Rydberg atoms (see box), as these distort the field much less. The “OnMicro” project aims to use Rydberg atoms to measure electric fields on wafers, which is useful in the manufacture of integrated circuits. For this purpose, the state of the art in the field of Rydberg atoms is to be improved by means of a measuring cell specially designed for this measurement and an improved read-out technique. This goal is pursued in cooperation with the University of Basel.

In order to have direct access to this technology at METAS and to be able to control further developments and new applications ourselves, a second project “QUSPR” (QUantum Sensing on Planar RF circuits) was launched. This involves setting up a laboratory for Rydberg atoms which replicates the successful preliminary work of the University of Basel in the “OnMicro” project but uses caesium atoms instead of rubidium. The advantage of caesium is its natural isotope purity, which enables more precise measurements than rubidium.



Alkali vapour cell (blue tube, centre) for atoms in Rydberg states. At the bottom of the picture, the gold coloured horn antenna for the electric fields can be seen.

Fluorescence of the red laser in the rubidium vapour, captured with an infrared camera.



Measurement set-up with blue and red laser beams made visible (red laser is barely identifiable).

Rydberg atoms

Rydberg atoms are atoms that are virtually ionised. This means that the outermost electron is far away (up to 500 nm) from the atomic nucleus, causing external electric fields to have a strong influence on the atom. This leads to a splitting of spectral lines proportional to the field strength, enabling the field strength of the Rydberg atom to be converted into a frequency. From a metrological point of view, this is extremely desirable, as frequencies can be measured with a very high level of accuracy.

TDIS – dissemination of high-precision time scales

Given the current reliability challenges, White Rabbit (WR, see box) has proved to be a promising technology for the high-precision dissemination of time scales over optical fibres. This method offers a robust alternative to the satellite technologies currently in use and enables companies and strategically important institutions to ensure the optimal reliability of their systems.

The “TDIS” (Time DISsemination) project is a cooperation between METAS, the SWITCH Foundation, the Swiss National Research and Education Network (NREN), Armasuisse and the SIX Group, which is responsible for the infrastructure of the Swiss Stock Exchange.

The main objective was to develop a prototype network to evaluate the performance of WR technology as a solution for high-precision time dissemination services in Switzerland that are reliable over long distances.

This prototype network links the cities of Bern, Basel, Zurich, Olten and Neuchâtel via a loop of around 500 kilometres. It was able to measure the dissemination of the official Swiss time scale (UTC[CH]) with an accuracy of better than a nanosecond, confirming that WR can be used as a credible alternative to current time dissemination techniques. In addition, this network operates in the “L-band” (wavelength: 1565–1625 nm) and is therefore not in competition with traditional data traffic in the “C-band” (wavelength: 1530–1565 nm). As a result, WR remains compatible with existing fibre-optic telecommunications networks in Switzerland.

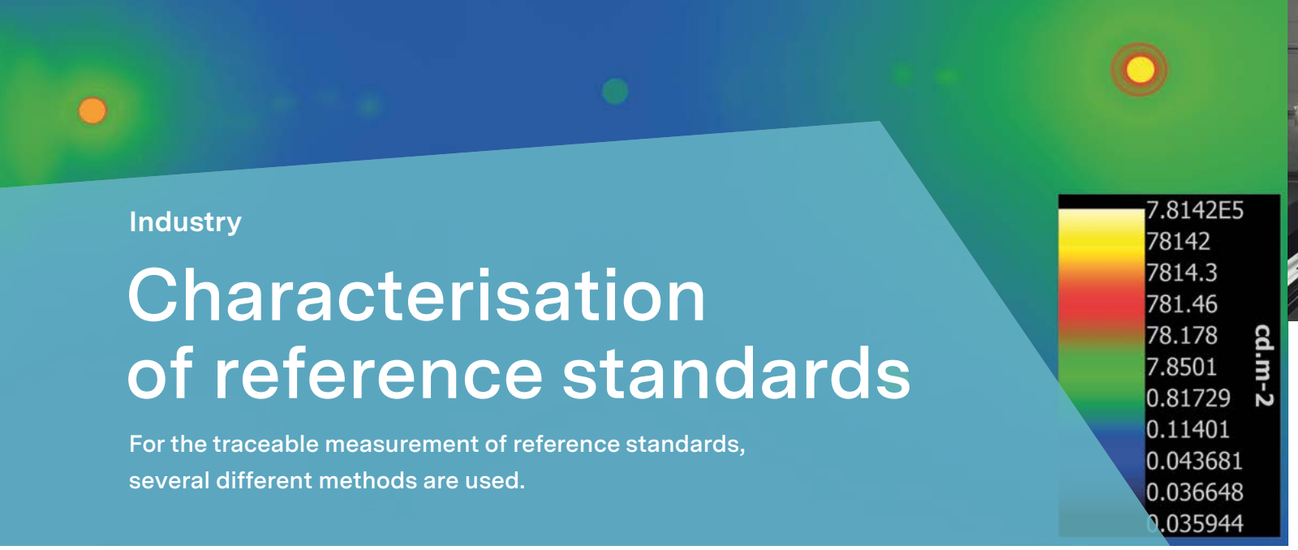
How WR works

White Rabbit (WR) enables the high-precision transmission of time information via optical fibres with an accuracy of up to a few dozen picoseconds (10^{-12} s). A WR connection between two points consists of two opposing signals (Rx for receive and Tx for send). By compensating for the transmission time difference of these signals, WR can achieve this level of precision. The technology also compensates for disruptive effects such as changes in the length of the optical fibre due to temperature fluctuations, which ensures even greater stability.

Industry

Characterisation of reference standards

For the traceable measurement of reference standards, several different methods are used.



An HDR luminance image from the HiDyni source, captured by an imaging system (camera).

On the one hand, reference standards are set up to characterise measurement systems, as was the case in the "HiDyn" project. On the other hand, reference standards are also characterised with an integral detector (in the case of gloss standards) or with a scanning wave microscope (in the "ELENA" project).

Evaluation of glare and disturbing light with imaging systems

The "HiDyn" project aims to standardise high dynamic range (HDR) imaging systems for measuring luminance distribution, which is critical for assessing glare and disturbing light. These measurements are essential for the evaluation of LED- or laser-based car headlights and indoor/outdoor lighting.

The project objectives are to create luminance reference standards with high dynamic contrast, to validate HDR luminance measurements, to develop a harmonised HDR algorithm and to draw up guidelines for measurement uncertainty estimation. This will support legislation on glare and disturbing light, improve safety and comfort in lit environments, and boost ergonomics at work and road safety.

The project is also developing tools and guidelines for traceable HDR measurements. The "HiDyn" project aims to ensure the reproducibility and comparability of HDR measurements and helps to reduce the risks associated with glare and disturbing light. This contributes to public safety, environmental protection and improved visual comfort in daylight and night lighting.

METAS has set up the HiDyni light source with a dynamic range of six decades and characterised and validated it with HDR imaging systems in accordance with the defined guidelines.

Website of the project "EPM 21NRM01 HiDyn"

Electrical measurements with high spatial resolution

Consumer electronics, innovative quantum technologies and applications for the Internet of Things are all based on semiconductors, where reliable characterisation of the electrical nano- and microscale properties are essential for European innovation and competitiveness. Measuring these properties enables the evaluation of critical parameters used to determine the performance of electronic materials and components.

To this end, METAS participated in the European project "ELENA" (ELEctrical NAnoscale metrology in industry). METAS used a scanning microwave microscope as the measuring instrument, which enables electrical measurements with high spatial resolution. As a metrology institute, the focus was on making the measurements reliable. Reference

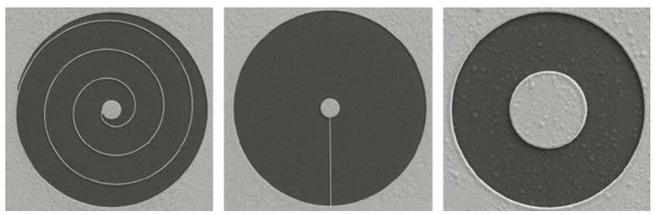
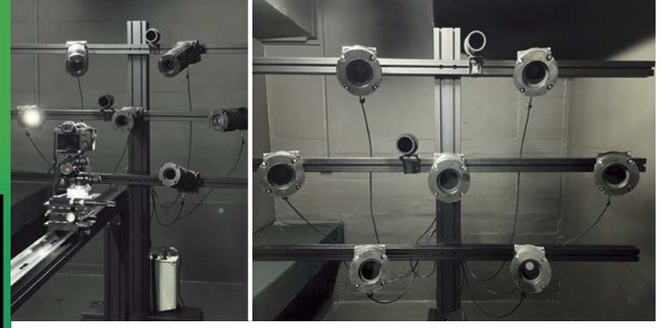


Fig. 1: Electron microscopic image of reference standards in the "ELENA" project.



The HiDyni source with high luminance contrast in action. Left: overall view, right: camera view.

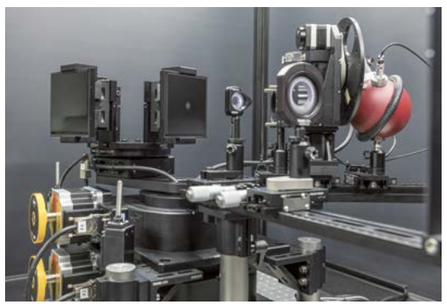
Website of the "ELENA" project

standards, robust calibration methods and software were developed for this purpose. The project made a significant contribution to establishing metrological principles for electrical measurements on small scales too, so that their accuracy can be quantitatively specified. Fig. 1 shows the gold structures on thin membranes manufactured by METAS using specialised procedures in the clean room at the CMI (Center of MicroNano Technology at EPFL) in Lausanne. From the geometry of the gold structures, the electrical properties of the standards can be calculated. The typical diameter of these standards is about forty micrometres.

Gloss – new measurements of appearance

The appearance of a surface can be defined by various parameters, including colour, gloss, transparency and texture. In recent years, three measuring stations for the characterisation of colour and texture have been developed in the Optics Laboratory. The portfolio of appearance measurements has now been expanded with a new measuring station for gloss measurements.

Gloss is defined as the ratio of the luminous flux of a given light source and a given reception angle reflected by an object in the specular direction (equal and opposite to the angle of incidence) to the luminous flux reflected by a glass with a specific refractive index in the specular direction. To differentiate the gloss of different samples, measurements are carried out on three geometries: 20° for high-gloss samples, 60° for medium-gloss samples and 85° for matt-gloss samples.

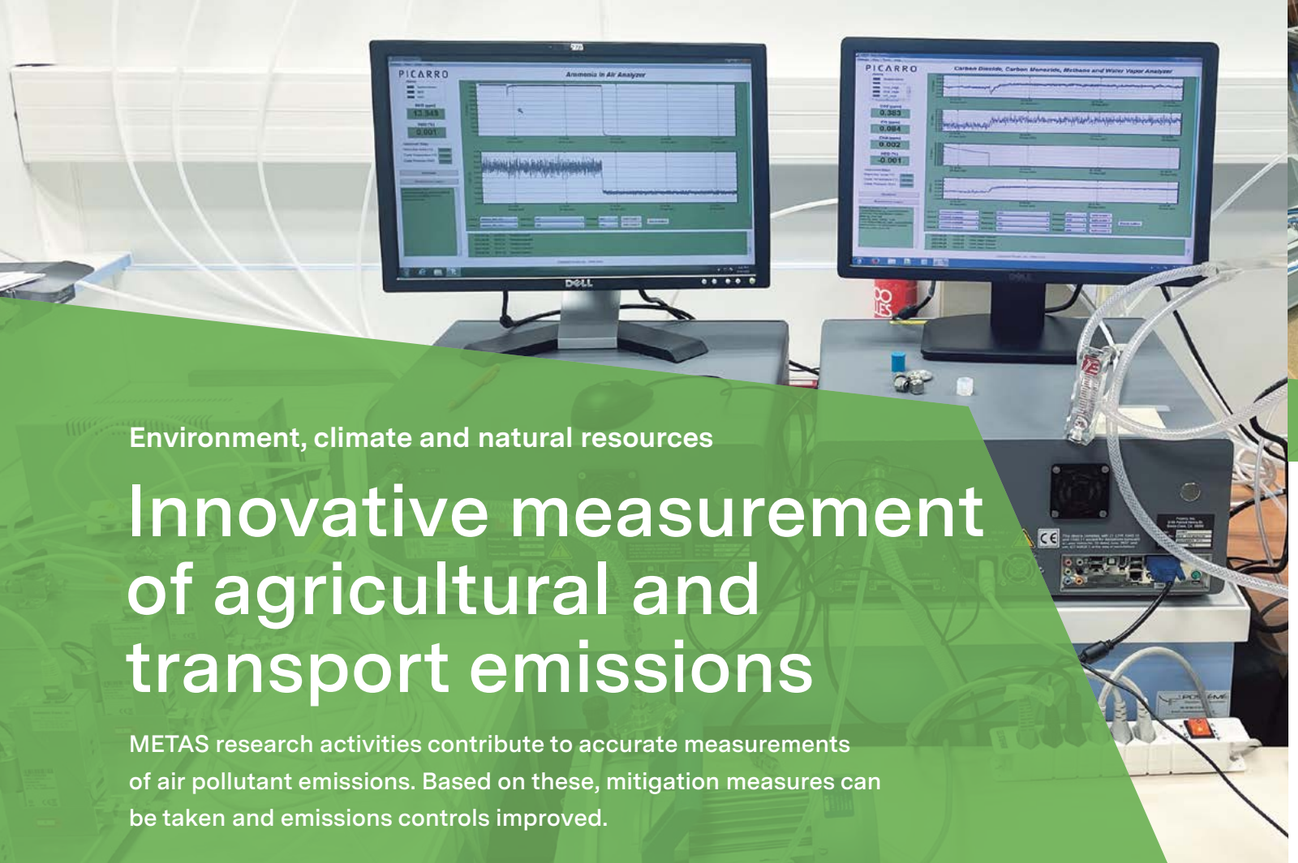


The measuring station for gloss measurements is ready to measure a high-gloss sample.

Gloss scale from low gloss (top) to high gloss (bottom).

The gloss measurement set-up enables automatic measurement of up to four samples at the same time with three different measurement geometries. The target measurement uncertainty is less than 0.5 gloss units for high-gloss samples. The measuring station is suitable for a wide range of sample sizes, from 55 × 15 mm to 115 × 115 mm.

To validate this measuring station, an international measurement comparison (EURAMET.PR-S7.2024) was initiated to measure gloss. METAS is assuming the role of the pilot laboratory, with NRC (Canada) and LNE (France) as participating laboratories. This measurement comparison enables METAS to obtain CMCs in the area of gloss measurement.



Environment, climate and natural resources

Innovative measurement of agricultural and transport emissions

METAS research activities contribute to accurate measurements of air pollutant emissions. Based on these, mitigation measures can be taken and emissions controls improved.

Emissions of air pollutants can harm people and their natural environment. Accurate measurements are essential to detect and reduce emissions locally. The emission of ammonia from livestock farming and the release of soot particles from diesel engines are two topics that METAS is addressing in research projects. The following examples from METAS laboratories show how innovative measurement approaches can improve the understanding of agricultural and transport emissions.

SI-traceable measurement of ammonia emissions from livestock farming

Excessive nitrogen emissions affect human health and biodiversity in near-natural ecosystems around the world. One of the largest sources of these emissions in Europe is livestock farming, which releases nitrogen into the atmosphere in the form of ammonia (NH_3).[1] Efforts to reduce these emissions are hindered by large uncertainties in emission calculations. Reliable and SI-traceable monitoring is therefore essential to implement effective mitigation strategies. This objective is pursued as part of the European research project “quantiAGREMI”, in which METAS plays a key role.

For reliable NH_3 measurements in barns and sheds, suitable reference gas mixtures with a similar composition to the sampled air are required. This is challenging because NH_3 is reactive and the barn air is moist and contains many components that can interfere with the measurements. In response to this need, the METAS gas analysis laboratory has further developed a mobile reference gas generator (ReGaS3) to produce humid, SI-traceable reference gas mixtures in situ.

As part of the research project, a test barn of the Swiss Federal Competence Centre for Agricultural Research (Agroscope) was also used to test whether measuring instruments correctly record the NH_3 content in the barn air and which materials are suitable for sampling the air. Thanks to these findings and the mobile reference generator, NH_3 measurements with lower uncertainty can now be carried out in barns and sheds.

1 Sutton, Mark A., et al., eds. The European Nitrogen Assessment: Sources, Effects and Policy Perspectives. Cambridge University Press, 2011.

Evaporator for humidification of the reference gas mixtures.

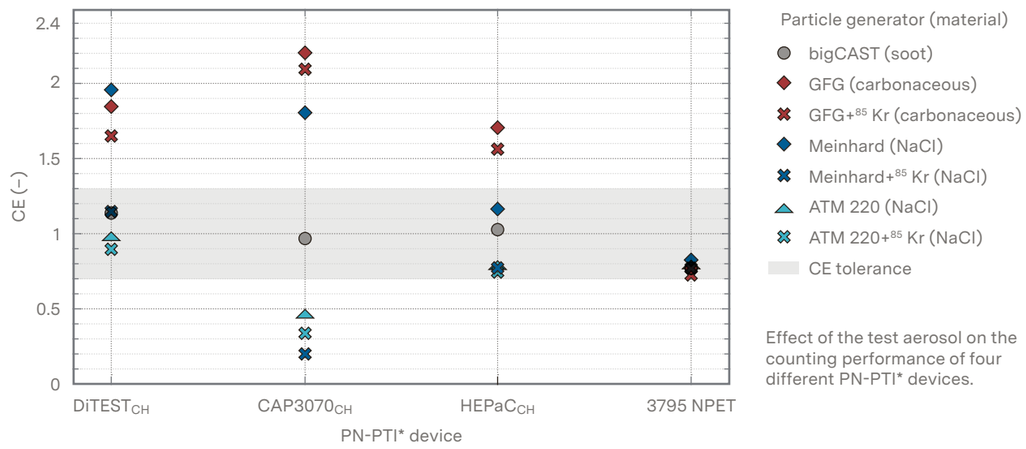
Gas generator (ReGaS3) for producing reference gas mixtures.

Article on the effect of the test aerosol on the measuring efficiency of particle counters

Effect of the test aerosol on the measurement efficiency of particle counters

Vehicles contribute significantly to air pollution in most urban areas. Equipping diesel engines with diesel particulate filters (DPFs) was a major step forward in emissions control. However, in some cases, DPFs are tampered with or are defective, so that particulate emissions from vehicles may exceed the type-approval limit. This means that a small proportion (around 10 %) of vehicles can be responsible for up to 80–90 % of total fleet emissions.

In order to reduce particulate emissions from diesel engines with particulate filters, a new procedure for periodic technical monitoring of vehicles based on particle count measurement has been introduced in Switzerland. A study led by METAS investigated how the choice of the test aerosol affects the measuring efficiency of the particle counters. The measuring efficiency of certain instruments depends heavily on the morphology of the test parts. The comparison with a diesel engine without a DPF showed that combustion aerosols from commercial aerosol generators are the best proxy for soot emissions from diesel vehicle engines. This finding can help government authorities to optimise the process of calibrating the particle counters and testing them annually.



Effect of the test aerosol on the counting performance of four different PN-PTI* devices.

* PN-PTI: Particle Number - Periodic Technical Inspection.

National and international cooperation

Commitment to national and international organisations

METAS enjoys excellent links to national and international organisations and participates actively in their important committees. METAS is generally valued as a competent and reliable partner.

Collaboration is essential in the field of metrology (see pages 10 and 11, “Research and development”). Only such cooperation made it possible to replace the multitude of coexisting regional units of measurement and unit systems with the International System of Units (SI) now valid worldwide. Internationally harmonised requirements for measuring instruments and measuring methods make it possible to use them in trade in the first place. Accordingly, national and international cooperation is of particular importance to METAS.

International cooperation principally takes place within the framework of the European Association of National Metrology Institutes (EURAMET). The European Cooperation in Legal Metrology (WELMEC) also plays a key role.

Within Switzerland, METAS maintains long-term commitments to national societies/professional organisations (e.g. Electrosuisse, SCS, SGSMP, SLG, SFC, SPS) and standardisation bodies (e.g. CES, SNV, VSS) as well as to Swissmem in the Swiss Quantum Industry Network.

A selection of representations of METAS specialists in committees and institutions

Dr Philippe Richard, CIPM (BIPM): The Director of METAS has been Vice President of the CIPM since March 2023. Richard is also President of the CIPM Sub-Committee on Finance and the CIPM Sub-Committee on Governance.

Dr Fabiano Assi, SAS: The Physics Division Manager at METAS has been a member of the Federal Accreditation Commission (AKKO) of the Swiss Accreditation Service (SAS) since 1 January 2024.

Dr Hanspeter Andres, EURAMET: The Chemistry and Biology Division Manager at METAS has been a member of the Board of Directors of EURAMET since 30 May 2023.

Dr Bobjoseph Mathew, CIML (OIML): The Legal Metrology Division Manager at METAS has been President of the International Committee of Legal Metrology (CIML) since October 2023. This is the decision-making authority of the International Organization of Legal Metrology (OIML). Mathew has been elected CIML President for a term of six years.

Dr Peter Blattner, CIE and **CIPM:** After his years in office as CIE President, the Chief Metrology Officer (CMO) of METAS still supports the CIE Executive Board in his capacity as Past President. He has also been a delegate to the CIPM Forum on Metrology and Digitalization since November 2023.

Dr Hugo Lehmann, IMEKO and **CIM:** The Chief Partnership and Technology Transfer Officer at METAS has been the Swiss delegate to IMEKO since September 2023. In August 2024, he represented Switzerland on the IMEKO General Council and at the IMEKO World Congress in Hamburg. Hugo Lehmann is also a member of the Organising Committee of CIM2025 in Lyon.

A selection of the national and international organisations and associations

National

CES
Swiss standardisation organisation for electrical engineering
›electrosuisse.ch

Electrosuisse
Professional organisation for electrical engineering, energy and information technology
›electrosuisse.ch

SCS
Swiss Chemical Society
›scg.ch

SGSMP
Swiss Society of Radiobiology and Medical Physics
›ssrpm.ch

SLG
Swiss light society
›slg.ch

SFC
Swiss Society for Food Chemistry
›swissfoodchem.ch

SPS
Swiss Physical Society
›sps.ch

SNV
Swiss Association for Standardization
›snv.ch

Swissmem
Association of the Swiss tech industry (machinery, electrical and metal industries as well as related technology sectors)
›swissmem.ch

VSS
Swiss Association of Road and Transport Experts
›vss.ch

International

BIPM
International Bureau of Weights and Measures
›bipm.org

CEN/CENELEC
European Committee for Electrotechnical Standardization
›cencenelec.eu

CGPM
Conférence Générale des Poids et Mesures
›bipm.org

CIE
International Commission on Illumination
›cie.co.at

CIM
International Metrology Congress
›cim-metrology.org

CIPM
Comité International des Poids et Mesures
›bipm.org

EMETAS
European Metrological Type Approvals Service
›emetas.net

EURACHEM
A Focus for Analytical Chemistry in Europe
›eurachem.org

EURAMET
European Association of National Metrology Institutes
›euramet.org

IEC
International Electrotechnical Commission
›iec.ch

IMEKO
International Measurement Confederation
›imeko.org

ISO
International Organization for Standardization
›iso.org

NoBoMet
Notified Bodies in Metrology
›nobomet.org

OIML
International Organization of Legal Metrology
›oiml.org

WELMEC
European Cooperation in Legal Metrology
›welmec.org

European Metrology Networks (EURAMET)

European metrology networks implement the vision of the world-leading metrology capacity of EURAMET and its members. Together they meet the rapidly progressing needs of end users with high-quality scientific research and an efficient and integrated infrastructure. This cooperation is crucial for METAS and Switzerland, which is why METAS actively participates in ten out of a current total of twelve metrology networks. In 2024, METAS joined the newly launched “Clean Energy” network.

Social and environmental responsibility

A year of development at METAS: from solution focus to energy efficiency

With workshops, training sessions and “RUMBA”, METAS has invested in continuous improvement and sustainable development in the past year.

In the past year, METAS has made significant progress in two areas: workshops on solution-focused action made all employees aware of the need for a more effective approach, while managers had the chance to develop their skills in targeted training sessions. METAS also achieved impressive success in increasing energy efficiency and sustainability through the RUMBA programme. These measures demonstrate METAS’ commitment to continuous improvement and sustainable development.

Solution focus workshops

In 2024, employees, managers and the Executive Board of METAS took part in one-day internal workshops on the topic of “solution focus”. This was the implementation of a measure from the 2023 staff survey (“Training: make all employees aware of the topics of ‘solution-oriented action’ and ‘error culture’”). The aim was for all employees to gain a personal benefit for their day-to-day work.

After brief presentations on theory, the workshop participants focused on consolidating what they had learnt in specific practical exercises. The content centred around areas such as “problem vs. solution”, “room for manoeuvre”, “roles”, “motivations” and “desired state”. Participants also had the opportunity to engage in a “fireside chat” with a member of the Executive Board.

So as not to lose sight of the implementation, all managers agreed on a conduct-related target for 2025 with their employees, which was based on solution focus.

The “pole game” makes it clear how incredibly challenging a group’s own coordination can be. Actually, the pole should simply have been placed on the floor …

METAS’ newest electric car at the outdoor charging station. Two of the four e-bikes are in front of it.

Leadership training

In 2024, all managers were given what is known as 270° feedback, meaning that they received feedback from their employees, colleagues and line managers. Based on this feedback, personal measures were derived for managers and common areas of development were identified. These formed the thematic basis for three one-day leadership training sessions on the topics “Communicating in an impact-oriented manner”, “Optimising collaboration despite tensions and mistakes” and “Managing and developing employees in a strength-oriented manner”.

All participants received a task at the end of each training session. In order to discuss the personal implementation measures, half-day “retrospectives” were held three months after the training sessions. To ensure that they continue to put their training into practice in 2025, all managers have been given a corresponding target by their line managers during their performance appraisal.

Window with an insight into the leadership training.

Protecting environmental resources means promoting energy efficiency

In 2024, METAS made impressive progress in energy efficiency through the consistent voluntary implementation of the RUMBA (Resource and Environmental Management of the Federal Administration) programme.

RUMBA aims to minimise energy consumption and environmental impact in federal buildings. Through targeted building technology measures, such as modernising heating, ventilation and air-conditioning systems and optimising conditions in offices and laboratories, METAS was able to reduce its environmental footprint.

Further investments were also made in e-mobility. In addition to the existing five electric cars, which consumed around 17 kWh/100 km on average, and the two e-bikes, another electric car was added in 2024. To supplement the charging infrastructure already in place in the METAS garage, electric cars can now also be charged at the additionally installed outdoor charging station in front of the main entrance.

Plans such as replacing the heating system and implementing a photovoltaic system to reduce CO_2 emissions have been presented to the Federal Office for Buildings and Logistics (FOBL) and are to be implemented in the coming years.

Resource and Environmental Management of the Federal Administration (RUMBA)

On behalf of the Federal Government

Reliable measurements for the public sector

METAS provides consulting services, measurement services and complex analyses such as sampling, maintenance and laboratory or on-site testing. It performs these activities on behalf of the Federal Government.

Various federal offices require ultra-reliable measurement services. METAS provides these to support a range of causes, including for the benefit of the Federal Roads Office (FEDRO), the Federal Office for Customs and Border Security (FOCBS), the Federal Office of Public Health (FOPH) and the Federal Food Safety and Veterinary Office (FSVO).

With its services, METAS supports the authorities with a reliable and high-quality assessment of the samples collected by the administration and any measurements ordered.

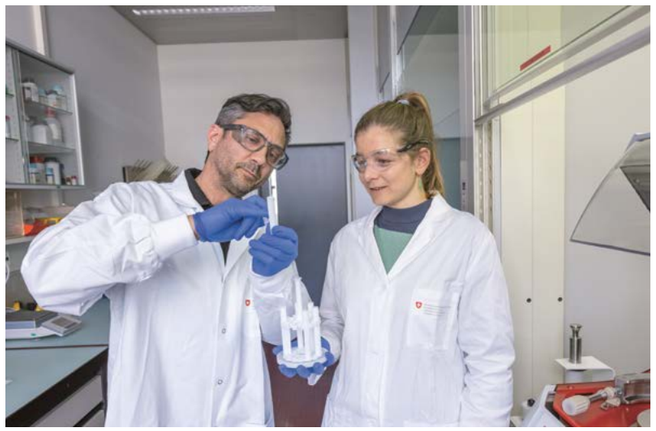
Chemical and biological analyses for national FSVO monitoring studies

Our health is influenced in a wide variety of ways.

With chemical and biological analyses, METAS provides effective support to the FSVO in its main task of actively promoting the health and well-being of people and animals.

Human biomonitoring studies, which collect data on the state of health, chemical exposure and nutritional status of the Swiss population, provide valuable information not only on its general state of health, but also on environmental influences on our health.

Various trace elements and toxic elements (iodine, copper, selenium, zinc, arsenic, lead, cadmium) and organic compounds (bisphenols, phthalates and per- and polyfluorinated alkyl compounds [PFAS]) are currently being determined at METAS for two different studies. This task also includes optimising the analysis methods to efficiently prepare and measure hundreds of samples for analysis.



Assessing the fill level of a sample tube before inserting it into the digestion device (bottom right in the picture). It digests blood, serum and urine samples for the subsequent element analysis.

Connecting the MetaSpeed to a stationary speed measuring instrument in Thun (canton of Bern).

MetaSpeed: new test equipment for induction loops

Induction loops are copper wires that are laid permanently in the road surface and can be used to detect vehicle passages.

If induction loops are used for official speed checks or red-light monitoring in road traffic, they must be verified annually by the Traffic technical field. During the on-site verification, electrical parameters are checked and a speed measurement comparison is carried out with a reference system. These test tasks are now all covered by the new MetaSpeed, a compact, robust and battery-operated piece of test equipment.

The MetaSpeed checks all induction loops on a road fully and automatically.

Four units were developed and produced with the help of internal and external partners. The MetaSpeed allows all induction loops on a road to be tested fully and automatically in just a few minutes. This significantly increases the efficiency, reliability and safety of verifications on busy roads.

METAS analyses support FOCBS goods inspections

For several years now, METAS has been supporting the Federal Office for Customs and Border Security (FOCBS) in controlling the cross-border movement of goods through chemical, physical and biological analyses. In 2025, 1459 samples were analysed from food to technical preparation. Because these samples had attracted the attention of FOCBS employees at the border, they were sent to METAS for in-depth analytical examination. In 15 % of the samples, discrepancies with regard to the declaration and/or the taxes or duties owed were analytically verified. In this way, METAS contributes to the reliability of goods declarations and fair taxation in the cross-border movement of goods.

Analytical services for METAS customers require a state-of-the-art laboratory and highly trained employees.

Metrology on the market

Precision for quality, safety and trust

Switzerland's quality infrastructure ensures that products and services meet the highest standards.

Whether industry, trade or consumer protection – a functioning quality infrastructure is essential. It ensures precise measurements, clear standards and reliable certifications. METAS makes a vital contribution by creating the metrological basis for precision, safety and fairness in the market.

METAS is an important part of the Swiss quality infrastructure

The quality infrastructure (QI) ensures the quality, safety and efficiency of products, services and processes. It is the backbone of modern economic systems, facilitates international trade, promotes technological development and protects consumers and the environment.

The term "quality infrastructure" is not to be confused with the "quality of infrastructure", such as the quality of roads, bridges or energy supply networks.

In a globalised world, businesses and consumers depend on a reliable system that ensures that products and services meet certain standards. A well-functioning QI improves the competitiveness of companies, facilitates market access and minimises technical barriers to trade. It promotes innovation and ensures that legal requirements are fulfilled.

QI is based on five key, closely interlinked pillars: metrology; standardisation; accreditation; certification, inspection and testing; and regulation.

METAS is Switzerland's national **metrology** institute (NMI). As such, its task is to ensure that measurements can be made in Switzerland with the accuracy required for the needs of business, research and administration.

The Swiss Association for Standardization (SNV) coordinates the development, adoption and implementation of **standards** in various economic sectors. Many experts support standardisation activities at national and international level in various standardisation bodies.

Swiss Association for Standardization (SNV)

Accreditation means the formal recognition of the professional and organisational competence of a body to perform a specific service described in the scope of the accreditation. The Swiss Accreditation Service SAS assesses and accredits conformity assessment bodies (CABs) on the basis of the corresponding international standards. METAS supports accreditation activities by having many of its experts acting as technical assessors.

In addition to calibrations, METAS also carries out **inspections and tests** in accordance with international standards. The accredited conformity assessment body METAS-Cert is the EU-recognised body designated by Switzerland for the conformity assessment of measuring instruments and performs the conformity assessments prescribed for manufacturers (see box).

Swiss Accreditation Service SAS

Federal Act on the Federal Institute of Metrology (EIMG, SR 941.27)

With the implementation of the Metrology Act, METAS is also active in the area of **regulation.** In addition, it supports other federal agencies with legislation on all metrological issues. The other tasks are set out in the Federal Act on the Federal Institute of Metrology (EIMG).

Contribution of METAS-Cert to the quality infrastructure

METAS has established the METAS-Cert conformity assessment body on the basis of the bilateral agreements with the EU (since 2004).

Conformity assessment body METAS-Cert

METAS-Cert carries out conformity assessments for measuring instruments, such as type examinations, certification of quality assurance systems and product tests. Measuring instruments that have passed a conformity assessment bear the metrological CE marking (see title image): a rectangle with the metrology "M", year number and identification number of the notified body[1] (METAS-Cert: 1259).

These certifications enable manufacturers to bring their measuring instruments to the Swiss and European markets in a compliant manner. METAS-Cert operates worldwide.

Institutions of the Swiss quality infrastructure

Metrology: METAS guarantees that measurements can be traced back to internationally recognised implementations of measurands and units.

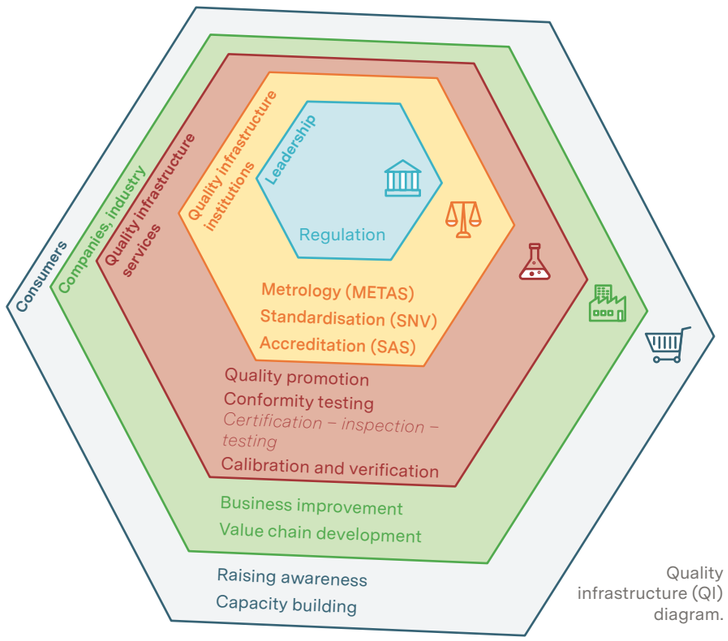
Standardisation: The SNV coordinates the development, adoption and implementation of standards in various economic sectors.

Accreditation: The SAS guarantees the competence of inspection and certification bodies.

Measuring instruments harmonised with the EU: balances, water meters, gas meters, electrical energy meters, heat meters, measuring systems for liquids other than water, capacity serving measures, measures of length and multidimensional measuring instruments.

At METAS-Cert, manufacturers receive a range of certifications from a single source. The measuring instruments placed on the market in this way can be used with confidence.

1 A "notified body" has been designated by a national authority and authorised to carry out conformity assessments for certain products before they are placed on the market.



Quality infrastructure (QI) diagram.

Product testing of a weighbridge.

Finances

METAS closed the 2024 financial year with a profit of CHF 921,000. Expenses amounted to CHF 59.6 million and revenues (including payments) totalled CHF 60.5 million.

Balance sheet	31.12.2024 in CHF 1,000	31.12.2023 in CHF 1,000
Cash and cash equivalents	30,916	27,355
Trade receivables	3,525	4,137
Receivables from research projects	4,552	2,557
Other receivables	175	193
Inventories	22	44
Prepaid expenses and accrued income	1,380	1,361
Current assets	**40,570**	**35,646**
Property, plant and equipment	21,891	22,039
Intangible assets	4,208	3,609
Non-current assets	**26,099**	**25,648**
Total assets	**66,669**	**61,294**
Trade payables	1,490	1,176
Liabilities to research projects	6,062	2,365
Other liabilities	989	1,046
Accrued expenses and deferred income	2,212	1,282
Short-term loans	366	366
Current provisions	1,475	1,559
Short-term liabilities	**12,594**	**7,794**
Long-term loans	732	1,098
Provision for pension fund liabilities	23,215	18,984
Provisions for loyalty bonuses	1,569	1,524
Long-term liabilities	**25,516**	**21,606**
Accumulated loss	–6,342	–7,209
Accumulated actuarial losses/gains	29,699	33,955
Reserves for non-current assets	4,281	3,413
Profit	921	1,735
Equity	**28,559**	**31,894**
Total liabilities	**66,669**	**61,294**

Profit and loss account	2024 1.1.2024–31.12.2024 in CHF 1,000	2023 1.1.2023–31.12.2023 in CHF 1,000
Fees	11,437	9,241
Payments from the Federal Government	25,918	25,681
Federal Government payment with directly attributable return service	8,684	8,921
Revenue from external funding (excluding research)	11,097	10,689
External funding for research	2,376	1,753
Other revenue	149	134
Gross revenue	**59,661**	**56,419**
Reduction in revenue	–5	–4
Own work	754	625
Net revenue	**60,410**	**57,040**
Profit from sale of fixed assets	**74**	**23**
Expenditure on materials and third-party services	**–3,145**	**–599**
Personnel expenses	–38,515	–37,091
Room expenses	–7,991	–7,772
IT expenses	–2,068	–1,783
Other operating expenses	–3,667	–3,939
Depreciation	–3,889	–3,917
Operating expenses	**–56,130**	**–54,502**
Financial revenue	22	9
Financial expenses	–20	–96
Financial result	**2**	**–87**
Tax expenses	**–290**	**–140**
Profit	**921**	**1,735**

In the reporting year, METAS was able to finance 58.1 % of its activities itself.
Fees, payments for taking on other tasks and external funding contributed to this self-financing.
The auditors confirmed without reservation that the accounts were in proper order.

METAS' financial reporting is carried out in accordance with the International Public Sector Accounting Standards (IPSAS)

METAS lectures and publications

METAS' research and development activities within the reporting year are also presented to the public in the form of lectures and publications.

In this reporting year, METAS scientists once again presented the results of their research and development work and their in-depth expertise in the form of lectures at symposia and conferences, and they wrote a considerable number of scientific publications on their results. Through their participation in professional organisations and committees, they also contributed their expertise and experience at national and international level. In this way, METAS researchers communicated information about metrology to a wider audience, including outside the immediate professional circles of the sector. They were also involved in courses for students at higher education institutions.

The following lists contain an overview of the most important presentations given by METAS employees as well as the publications published by them or with their involvement.

The presentations are sorted in ascending alphabetical order by the METAS keynote speaker, and the publications are sorted in ascending alphabetical order by the firstMETAS author to appear, then by the main authors and finally by the co-authors.

All names of METAS employees are highlighted in **bold.**

Lectures

A **André, M-A.** & **Pythoud F.,** Metrologie schafft Vertrauen, Präsentation für das Forensische Institut Zürich, 29.02.2024

Andres, H., Chemical and biological references at the Federal Institute of Metrology METAS, CHAnalysis 2024, Beatenberg, 10.04.2024

Andres, H., Metrology ermöglicht Vertrauen im täglichen Leben, IRM Basel Vortragsserie Herbst 2024, 13.11.2024

Assi, F., The journey to METAS, InSight – Materials Alumni berichten aus ihrem Arbeitsalltag, ETHZ, 19.03.2024

Auderset, K., Experiences with particle-measuring devices for PTI, VERT-NPTI Implementation Workshop, 21.03.2024

B **Bissig, H.,** Calibration of flow devices under actual flow conditions with inline measurement of the viscosity of the liquid, Conference on Microfluidic Handling Systems, 21.–23.02.2024, München (D), 22.02.2024

Bissig, H., Comparison of primary standards for liquid flow in the range from 0.1 µL/min to 10 µL/min, 24. IMEKO World Congress, Hamburg (D), 27.08.2024

Blattner, P., Digitalisation of Legal Metrology: Challenges and Opportunities, OIML Digitalization Task Group Webinar Series, online, 24.07.2024

Blattner, P., SI definition of the candela and high level objective of photometry, CCPR and CIE Expert Workshop – 100 Years of V(I) and the future of photometry, BIPM, Sèvres (F), 03.06.2024

Bodor, P., Akustika Herbstwebinar 2024, Akustika Herbstwebinar, online, 30.09.2024

Bühlmann, T., SI-traceable quantification of halogenated VOCs in the atmosphere, 1st CIPM STG-CENV Stakeholder Meeting, Paris (F), 17.09.2024

E **Eckmann, B.,** Scanning Microwave Microscopy for Biomedical Applications, CNB – Clinical Neuroscience Bern 2024, 06.09.2024

F **Frigo, G.,** An Uncertainty-based Criterion for Aggregation of Consistent ROCOF Measurements, 2024 International Conference on Smart Grid Synchronized Measurements and Analytics (SGSMA), Washington DC (USA), 21.05.2024

Frigo, G., DC power and energy and DCPQ reference systems with distorted signals, DC Grids Final Stakeholder Meeting, Delft (NL), 16.05.2024

Frigo, G., Inter-Laboratory Comparison of Reference Systems for DC Power Quality Measurements, 2024 IEEE 14th International Workshop on Applied Measurements for Power Systems (AMPS), Caserta (I), 19.09.2024

Frigo, G., Measurements for smart electricity grids: workshop and open consultation, EMN Smart Electricity Grids Annual Meeting, Delft (NL), 15.05.2024

Frigo, G., Transfer Standard for the Assessment of Spurious Emissions in DC Power, IMEKO 2024 XXIV World Congress, Hamburg (D), 27.08.2024

Frigo, G., Utilizing Matrix Profile for Enhanced Detection of Events in Sampled Values, 2024 IEEE 14th International Workshop on Applied Measurements for Power Systems (AMPS), Caserta (I), 18.09.2024

Fritsche, J., Generation of humid NH3 reference gas mixtures at trace levels, Gas Analysis 2024, Paris (F), 01.02.2024

Fritsche, J., Generators for continuous preparation of dry and humid NH3 reference gas mixtures, Special Session at Air Quality Conference, Helsinki (FIN), 14.05.2024

Fritsche, J., quantiAGREMI – Ammonia and greenhouse gas emissions from livestock farming, Picarro Ammonia Summit, Aarhus (DK), 20.03.2024

H **Hoffmann, J.,** S-Parameters on Printed Circuit Boards for Cryogenic Environment, CPEM 2024, Denver, CO, (USA) 08.07.2024

Hung-Ju, L., RF measurements for future communications applications, EPFL CMi Annual Review Meeting 2024, 14.05.2024

Husmann, D., Detection and analysis of anthropogenic patterns in a phase-stabilized optical fiber network, EFTF 2024, Neuenburg, 25.06.2024

Husmann, D., Exploiting frequency metrology fiber networks for earthquake sensing, SPS Annual Meeting 2024, Zürich, 12.09.2024

Husmann, D., Metrological frequency dissemination through a fiber optic network, QIDiS, Quantum Industry Days, Basel, 23.09.2024

Husmann, D., Time and frequency standards at METAS and their applications for precision measurements, PSAS 2024, International Conference on Precision Physics of Simple Atomic Systems, ETH Zürich, 10.06.2024

Huu de, M., Comparison of gravimetric standards for hydrogen refuelling stations, 24. IMEKO World Congress, Hamburg (D), 27.08.2024

Huu de, M., Dimension calibration of small critical flow Venturi nozzles, 24. IMEKO World Congress, Hamburg (D), 28.08.2024

Huu de, M., High pressure hydrogen metering, METAS-Seminar, 01.10.2024

I **Iturrate-Garcia, M.,** Assessing parameters affecting low-cost gas sensor response signal, EMN COO Annual General Meeting, 11.06.2024

Iturrate-Garcia, M., Assessing parameters affecting low-cost gas sensor response signals in the European photoreactor (EUPHORE) simulation chamber, Gas Analysis 2024, Paris (F), 31.01.2024

Iturrate-Garcia, M., Transferring metrological principles to low-cost sensors used in networks for air quality monitoring, 1st CIPM STG-CENV Stakeholder Meeting, Paris (F), 16.09.2024

J **Jallageas, A.,** Sub-ns long-haul dissemination of UTC(CH) using White Rabbit in Switzerland, CERN 2024 White Rabbit Workshop, 21.03.2024

Jallageas, A., White Rabbit in Switzerland: a first loop network for long-haul dissemination of UTC(CH), EFTF 2024, Neuenburg, 25.06.2024

L **Lauterbach, K-U.,** Koaxialkabel und deren Anwendung in der EMV, 65. Sitzung der PEGESS, Biel, 20.03.2024

Lehmann, H., METAS – The most accurate place in Switzerland, Federal Office Day, EPF Lausanne , 07.10.2024

Lehmann, H., METAS – The most accurate place in Switzerland, PolyMesse, ETH Zürch, 10.04.2024

Lehmann, H., Metrology for the 2nd Quantum Revolution, IMEKO 2024 World Congress, Hamburg (D), 26.08.2024

Lin, H., A novel Coaxial On-wafer Probe: Manufacturing and relevant Performance Tests, FutureCom Workshop at IEEE Symposium M&N 2024, 03.07.2024

M **Mallia, S.,** Authenticity of Swiss honey by trace element profile and stable strontium isotopic composition, Fachtagung NRL-MN, 21.11.2024

Mallia, S., ICP-MS- und ICP-OES Methode für die Analyse von Mikro- und Makroelementen in Fleisch- und Milchersatzsprodukten, Fachtagung NRL-MN, 21.11.2024

Mallia, S., News vom EURL-MN, 21.11.2024, Fachtagung NRL-MN, Fachtagung NRL-MN, 21.11.2024

Mallia, S., WP-CBR001 – A new matrix CRM to support food safety, ILMAC 2024 Lausanne, 19.09.2024

N **Niederhauser, B.,** Metrologie, METAS, Terminologie, Messunsicherheit, Konformität und Atemalkoholmessung, Vorlesung an der ZHAW Wädenswil im Rahmen vom Master Forensik, Modul Analytical Technologies, 02.12.2024

Niederhauser, B., New Absorption Coefficient for the UV-photometry of Ozone, Cercl'Air ERFA, Luzern, 05.09.2024

Niederhauser, J., Was ist eine Schaltsekunde und weshalb sollen Schaltsekunden nächstens abgeschafft werden?, SwissEngineering Fachgruppe Elektronik und Informatik (FAEL), FAEL-Herbstseminar «Zeit» – Uhrenindustrie Schweiz, PH Zürich, 20.11.2024

P **Peier, P.,** Radondosimetrie und Radonreferenz, ENSI Strahlenschutzseminar 2024, Windisch, 31.10.2024

Préville de, S., A Calibration Tool for Scanning Microwave Microscopy, ALTECH 2024 – Analytical techniques for accurate nanoscale characterization of advanced materials, Strasbourg (F), 27.05.2024

Préville de, S., Resistive standards for scanning microwave microscopy, EPFL CMi Annual Review Meeting 2024, 14.05.2024

Pythoud, F., Antennen-Symmetrie, 66. PEGESS-Sitzung, 10.02.2024

Pythoud, F., Konformitätsbeurteilung von Basisstationen, Cercle Air Sitzung, Zürich, 12.09.2024

R **Roos, D.,** METAS: the new WMO-GAW Central Calibration Laboratory for halogenated VOCs, CHAnalysis 2024, Beatenberg, 11.04.2024

T **Tas, E.,** METAS' Activities on 5G NR RF Exposure, Austauschplattform «Mobilfunk der Zukunft», Verantwortung BAFU, fand im METAS statt, 01.11.2024

Tas, E., Traceability of 5G NR RF Exposure Measurements, EUCAP 2024, Glasgow (UK), 22.03.2024

V **Vasilatou, K.,** PN-PTI in Switzerland: regulations, research findings and next steps, VERT-NPTI Workshop, 06.12.2024

Vasilatou, K., Primary standards and calibration strategies for filter photometers and aerosol spectrometers, EMN COO Annual General Meeting, 11.06.2024

Vasilatou, K., Type approval and verification of particle-measuring devices for PTI, CALAC+ Workshop «Challenges in Implementing Technologies for Cleaner Transport in Latin American Cities», 09.08.2024

Z **Zeier, M.,** Introduction to S-Parameter Metrology, BIPM CCEM Webinar, 25.01.2024

Zeier, M., VNA Tools - a metrology software supporting the digital traceability chain, IMEKO 2024 Workshop on Digital Traceability, Hamburg (D), 28.08.2024

Reader survey on the annual report

Please take a moment to complete the readers survey on the "METAS in 2024" annual report. METAS would like to get to know you a little better and find out if anything could be improved in the next edition.

There are eleven questions for you to answer, some of which are optional. It will take you around five minutes. You can complete this survey completely anonymously, or you are welcome to tell us a little more about yourself.

METAS is very excited to read your answers!

To start the reader survey please scan the QR code

Publications

A **Agustoni, M.** & **Frigo, G.,** Characterization of Analog Front-End in PMU Design for Inertia Monitoring, doi: 10.1109/I2MTC60896.2024.10560540.

Agustoni, M. & **Overney, F.** & **Eichenberger, A.-L.** & Kučera, J., Accurate Comparison of Calculable HF Resistance Standards, doi: 10.1109/CPEM61406.2024.10646143.

B Faghih Niresi, K. & **Bissig, H.** & **Baumann, H.** & Fink, O., Physics-Enhanced Graph Neural Networks for Soft Sensing in Industrial Internet of Things, in: IEEE Internet of Things Journal (11), doi: 10.1109/JIOT.2024.3434732.

Guzzini, A. & **Bissig, H.** & Saccani, C. et al., Hydrogen in natural gas grids: prospects and recommendations about gas flow meters, in: International Journal of Hydrogen Energy (86), doi: 10.1016/j.ijhydene.2024.08.344.

Blattner, P. & Brown, R. J. C., Relating SI units to the 'defining constants', in: Metrologia (61), doi: 10.1088/1681-7575/ad4cef.

Martinsons, C. & **Blattner, P.** & Herf, M. et al., Reconsidering the spectral distribution of light: Do people perceive watts or photons?, in: Lighting Research & Technology (56), doi: 10.1177/14771535241246060.

Breuninger, E. S. & **Bouchet, S.** & Mestrot, A. et al., Marine and terrestrial contributions to atmospheric deposition fluxes of methylated arsenic species, in: Nature Communications (15), doi: 10.1038/s41467-024-53974-z.

Müller, E. & **Bouchet, S.** & Winkel, L. H. E. et al., Reactions of hypobromous acid with dimethyl selenide, dimethyl diselenide and other organic selenium compounds: kinetics and product formation, in: Environmental Science: Water Research & Technology (10), doi: 10.1039/D3EW00787A.

ThomasArrigo, L. K. & **Bouchet, S.** & Nydegger, T. et al., Emerging investigator series: Coprecipitation with glucuronic acid limits reductive dissolution and transformation of ferrihydrite in an anoxic soil, in: Environmental Science: Processes & Impacts (26), doi: 10.1039/D4EM00238E.

Spitschan, M. **Bouroussis, C. A.** & **Caspar, P.** et al., Illuminating the future of wearable light metrology: Overview of the MeLiDos Project, in: Measurement (235), doi: 10.1016/j.measurement.2024.114909.

Burkhard, S. & **Küng, A.,** Beam hardening correction based on image noise statistics, in: Measurement Science and Technology (35), doi: 10.1088/1361-6501/ad2d4f.

Burkhard, S. & **Küng, A.,** Exact computation of projected sphere centres in cone beam x-ray projections, in: Measurement Science and Technology (35), doi: 10.1088/1361-6501/ad3bde.

C **Cen, T.,** Development of Hyphenated Analytical Techniques using spICP-MS for Online Characterization of Metallic Nanoparticles in Aerosols, doi: 10.5075/EPFL-THESIS-10787.

Cen, T. & Torrent, L. et al., Rotating disk diluter hyphenated with single particle ICP-MS as an online dilution and sampling platform for metallic nanoparticles characterization in ambient aerosol, in: Journal of Aerosol Science (175), doi: 10.1016/j.jaerosci.2023.106283.

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Cen, T. & Zhao, Y.-B. & Testino, A. et al., Dilution versus fractionation: Separation technologies hyphenated with spICP-MS for characterizing metallic nanoparticles in aerosols, in: Journal of Aerosol Science (177), doi: 10.1016/j.jaerosci.2023.106317.

Turhan, E. & **Corminboeuf, D.** et al., EURAMET.EM-S44 comparison for ultra-low DC current sources, in: Metrologia (60), doi: 10.1088/0026-1394/60/1a/01002.

E **Eckmann, B.** & **Lin, H.-J.** & **Préville de, S.** & **Hoffmann, J.** & **Zeier, M.** et al., Coaxial tips for a scanning microwave microscope and its calibration with dielectric references, in: Measurement Science and Technology (35), doi: 10.1088/1361-6501/ad480d.

Eichenberger, A. L. & **Overney, F.** & **Agustoni, M.,** Pulse Shape Optimisation of a Josephson Arbitrary Waveform Synthesizer, doi: 10.1109/CPEM61406.2024.10646147.

F Subiel, A. & **Frei, F.** & **Peier, P.** & Bourgouin, A. et al., Application of Primary Standards in Flash Radiotherapy, in: International Journal of Particle Therapy (12), doi: 10.1016/j.ijpt.2024.100238.

Frigo, G. & Castello, P. & Gallus, G. et al., Internal Time Reference Enhancement via White Rabbit Synchronization: A Power System Measurement Perspective, doi: 10.1109/SGSMA58694.2024.10571544.

Frigo, G. & Gallus, G., Transfer standard for the assessment of spurious emissions in DC power, in: Measurement: Sensors, doi: 10.1016/j.measen.2024.101716.

Frigo, G. & Gallus, G. & Pegoraro, P. A. et al., Combining Steady-State Accuracy and Responsiveness of PMU Estimates: An Approach Based on Left and Right Taylor–Fourier Expansions, in: IEEE Transactions on Instrumentation and Measurement (73), doi: 10.1109/TIM.2024.3384553.

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Frigo, G. & Macii, D. & Petri, D., Accuracy Comparison of Frequency and ROCOF Dynamic Estimators under Contingencies, doi: 10.1109/I2MTC60896.2024.10560661.

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Frigo, G. & Pegoraro, P. A. & Toscani, S., Compressive Sensing Taylor-Fourier Multifrequency Approach for Three-Phase Signals, doi: 10.1109/AMPS62611.2024.10706694.

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Agazar, M. & **Frigo, G.** & Giordano, D. et al., Power Grids and Instrument Transformers up to 150 kHz: A Review of Literature and Standards, in: Sensors (24), doi: 10.3390/s24134148.

Castello, P. & **Frigo, G.** et al., Utilizing Matrix Profile for Enhanced Detection of Events in Sampled Values, doi: 10.1109/AMPS62611.2024.10706669.

Elg, A.-P. & **Frigo, G.,** Rietveld, G. et al., High-Voltage Metrology for Electric Energy and Supply Reliability, doi: 10.1109/CPEM61406.2024.10646152.

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G **Guignard, F.** & Ginsbourger, D. & Levy Häner, L. et al., Some combinatorics of data leakage induced by clusters, in: Stochastic Environmental Research and Risk Assessment (38), doi: 10.1007/s00477-024-02715-1.

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Karpisz, T. & **Hoffmann, J.** & Evans, S. R. et al., On-Wafer Calibration Comparisons of Multiline TRL With Platinum and Gold Conductors, doi: 10.1109/IMS40175.2024.10600255.

Marzano, M. & **Hoffmann, J.** & Huang, N. et al., QuAHMET: Quantum anomalous Hall effect materials and devices for metrology, doi: 10.1109/CPEM61406.2024.10645997.

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I **Iturrate-Garcia, M.** & **Bühlmann, T.** & **Pascale, C.** et al., Accurate, Stable, and SI-Traceable Reference Gas Mixtures of VOCs Relevant for Climate at Atmospheric Levels, doi: 10.1007/978-3-031-47079-0_41.

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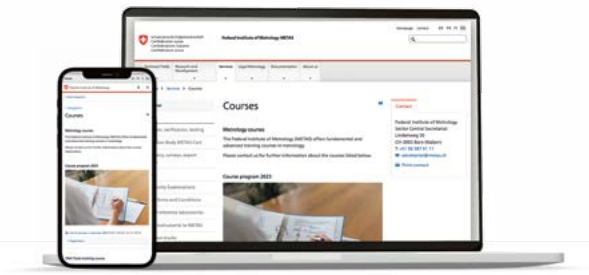

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