

muon.iverse

Klaus Kirch, Paul Scherrer Institute and ETH Zurich

MIP2026 [International Workshop on Muon Physics at the Intensity and Precision Frontiers](#), 25.04.2026

WHAT IS A NCCR?

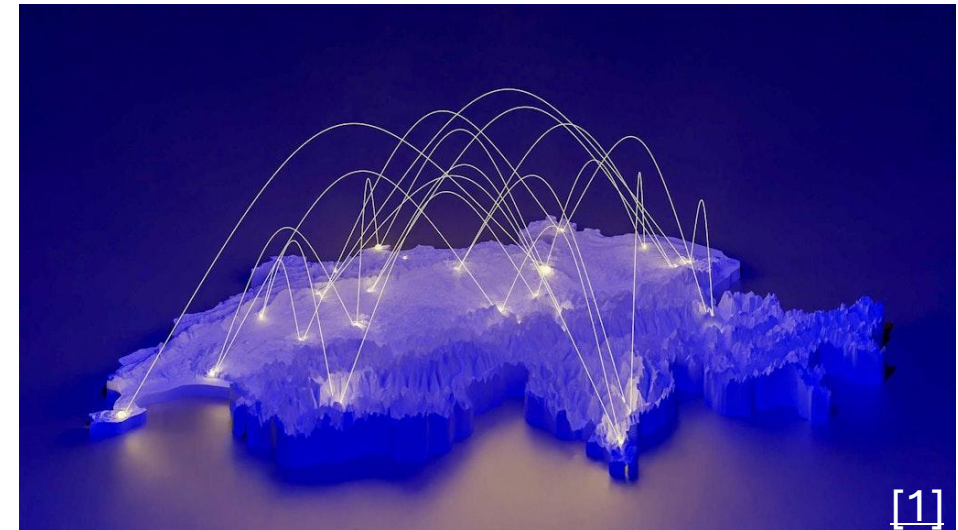


National Centres of Competence in Research (NCCRs) are intended to **give rise to new lasting structures**, showcase advanced research capabilities, and maintain the excellence and international positioning of Swiss research activities.

With this instrument, the federal government supports long-term **research projects of national importance**. NCCRs run for a **maximum period of 12 years**, receive federal funding supplemented by contributions from participating higher education institutions, third-party funding from research groups and contributions from the private sector.

Research within the NCCRs is carried out by **interdisciplinary teams** committed to the highest standards of quality and to **exploring innovative approaches**.

In addition, NCCRs play a vital role in **supporting early-career researchers**, in promoting the participation of **women in research**, and in fostering the **transfer of knowledge to industry**.



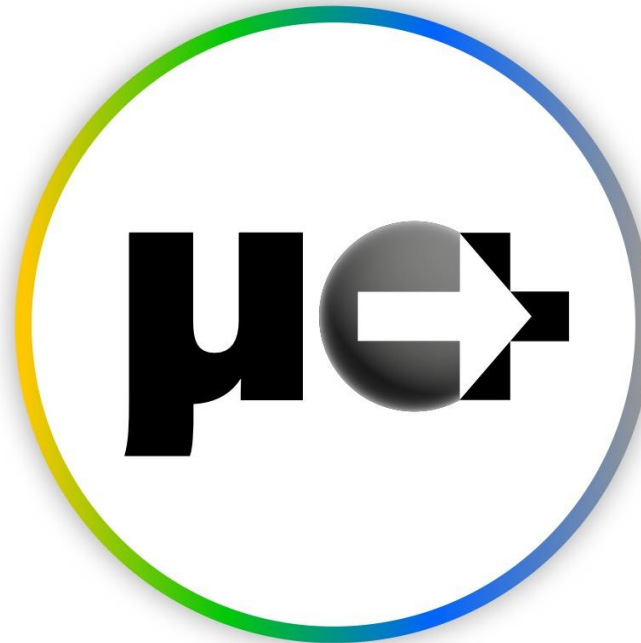
[1] <https://www.sbf.admin.ch/en/national-centres-of-competence-in-research>

[2] <https://www.wbf.admin.ch/en/newnsb/JEYzIEzRw1QFKXlPHWlxC>

[3] <https://www.snf.ch/en/EcRzGgwFJMZjfnNc/page/national-centres-of-competence-in-research-nccrs>



MUONIVERSE INSTITUTIONS & PARTNERS



Sammlungszentrum. SCHWEIZERISC
HES NATIONALMUSEUM. MUSÉE N
ATIONAL SUISSE. MUSEO NAZIONA
LE SVIZZERO. MUSEUM NAZIUNAL
SVIZZER.

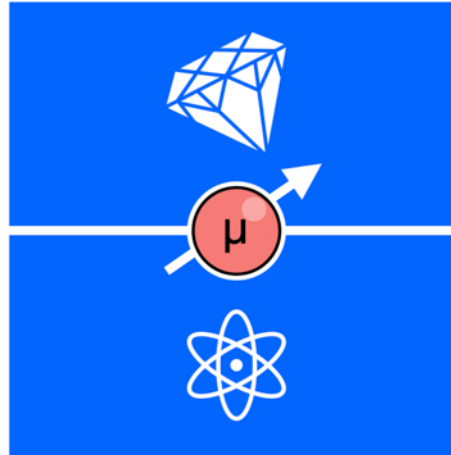
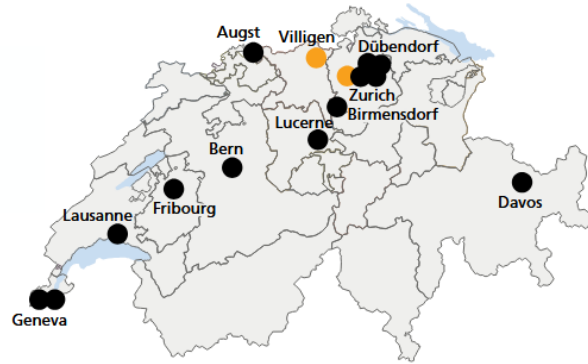


Muons for science and society — bridging discovery and application

National Centre of Competence in Research



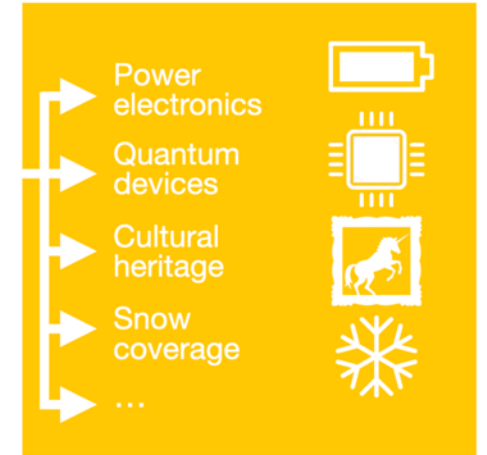
muoniverse



Muons are powerful and established probes of advanced materials and for high-precision particle physics



Technological developments within Muoniverse will drive a step-change in muon science

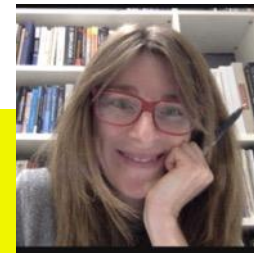


This step-change will open up the power of muons to new scientific domains and applications

- SNF funding ~14 MCHF (2026-29) plus cash and in-kind contributions from PSI and UZH
- **Total volume 33 MCHF/4 years**
- Three new professorships (2 joint PSI/UZH 80/20, 1 UZH)
- **12++ year perspective boosting leading muon science at PSI HIPA**
- www.muoniverse.ch



Klaus Kirch
Director



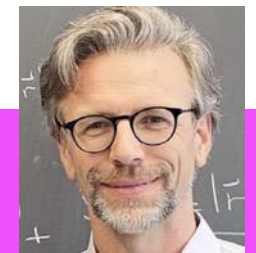
Angela Papa
Deputy Director



Leading House



Marc Janoschek
Co-Director



Titus Neupert
Deputy Co-Director



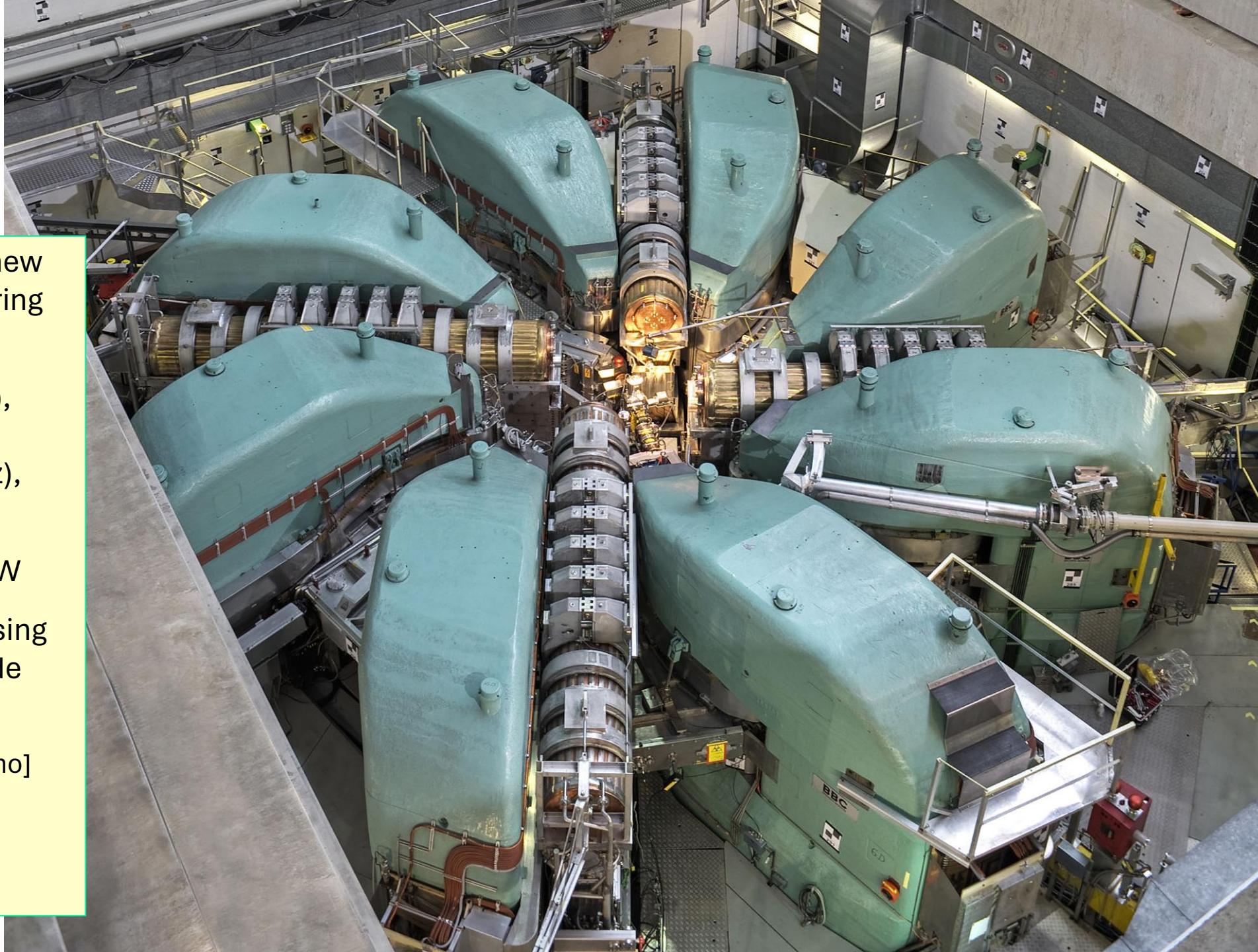
Universität Zürich
UZH

Co-Leading House

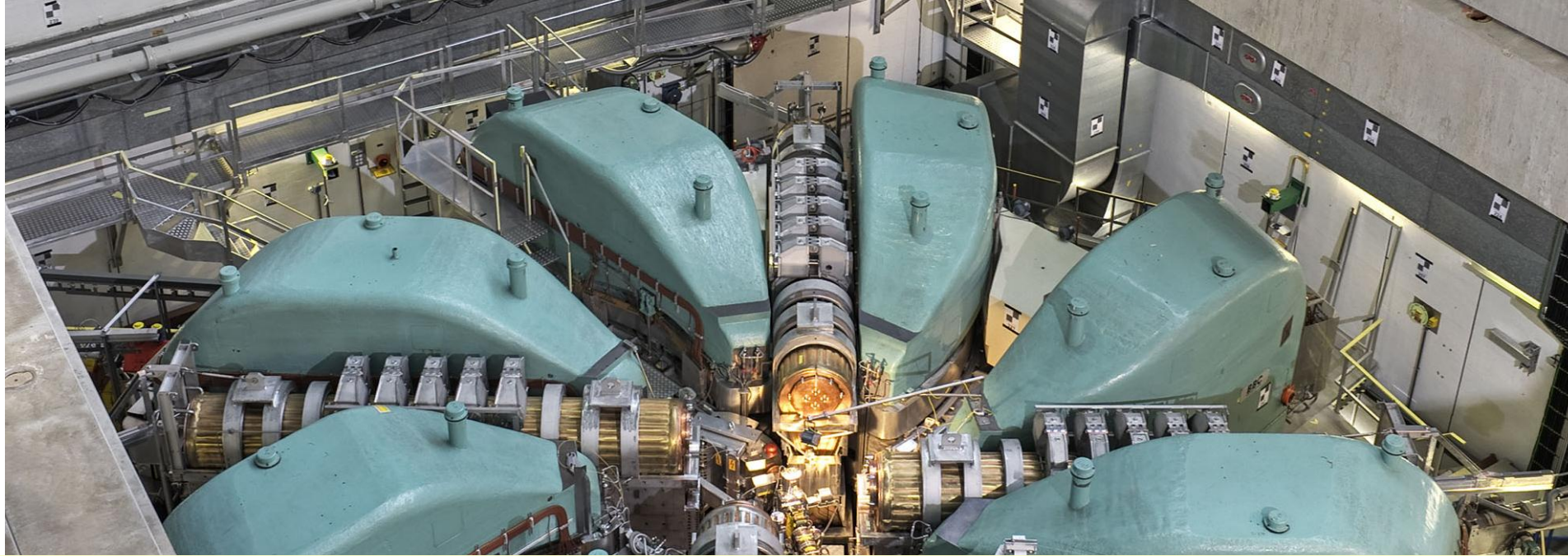
PSI HIPA

Ring cyclotron

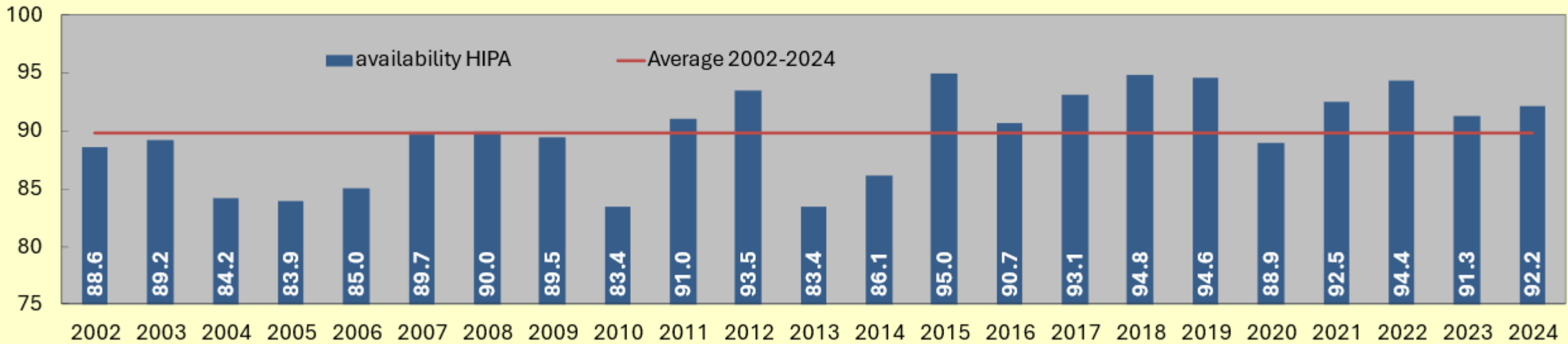
- at time of construction a new concept: separated sector ring cyclotron [H.Willax et al.]
 - 8 magnets (280t, 1.6-2.1T), 4 accelerating resonators (50MHz), 1 Flattop (150MHz), \varnothing 15m
 - losses at extraction ≤ 200 W
 - reducing losses by increasing RF voltage was main upgrade path
- [losses \propto (turn number)³, W.Joho]
- 590MeV protons at 80%c
 - 2.4mA x 590MeV=1.4MW



PSI HIPA Ring cyclotron

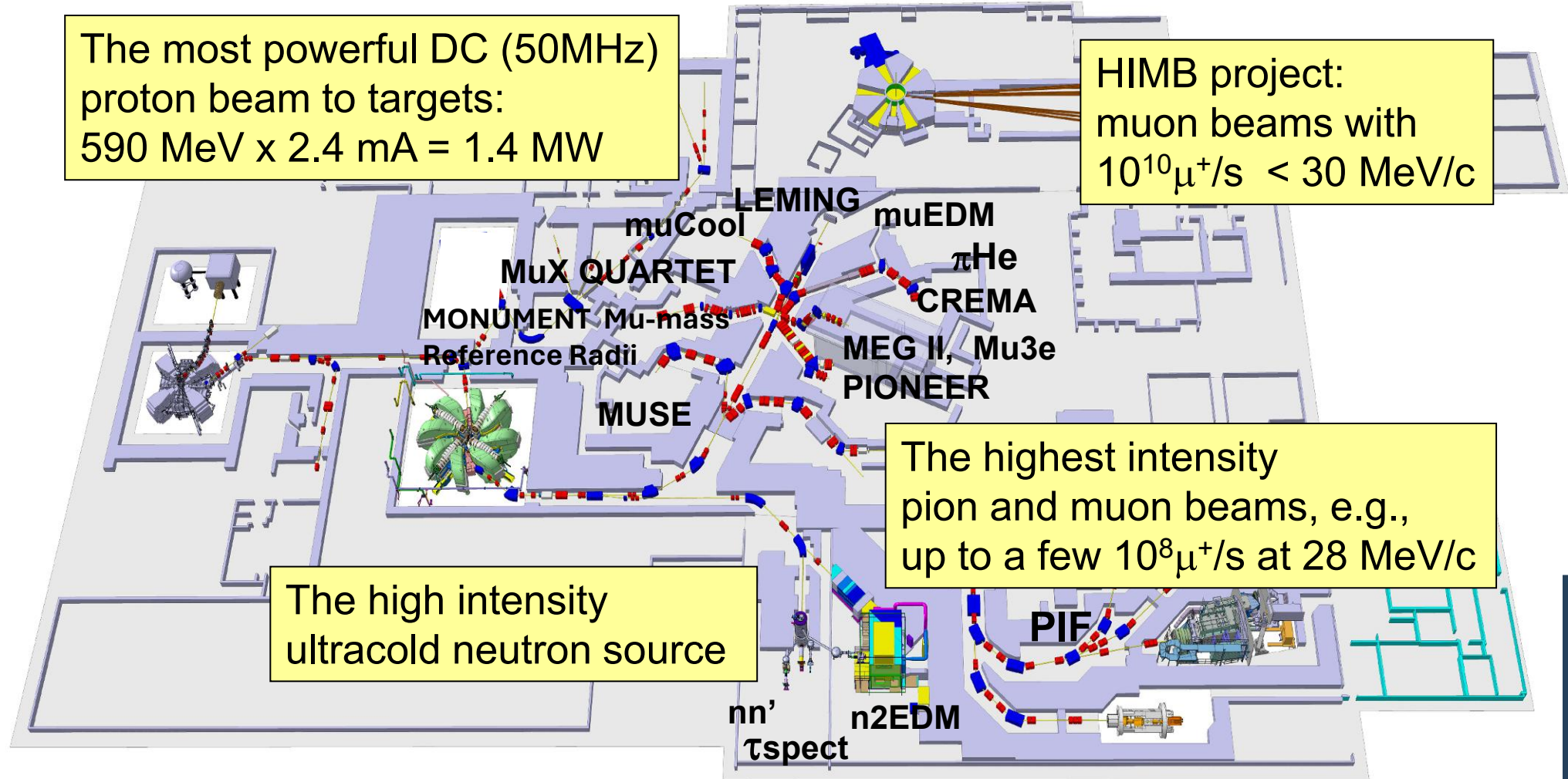


availability proton accelerator HIPA in %



CHRISP – Swiss Research Infrastructure for Particle Physics: PSI

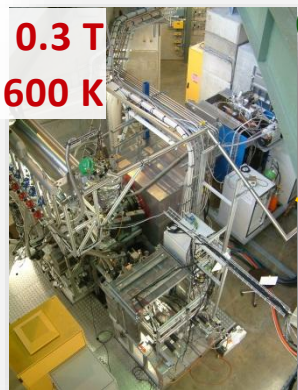
Precision experiments with the lightest unstable particles of their kind, π , μ , UCN



See recent Particle Physics at PSI, <https://scipost.org/SciPostPhysProc.5.001>



Instruments at the S μ S (Swiss Muon Source)



0.3 T
2.5 - 600 K

LEM

Thin films, devices

Low Energy Muon Facility

Muon Energy: 1-30 keV (μ^+)



DOLLY/VMS

Uniaxial pressure, 1 GPa

Muon Energy: 4 MeV (μ^+)

π E1 beam line shared with LTP, in operation 50% of the year

0.8 T
0.25 - 300 K
1 GPa uniaxial

GPD

Hydrostatic pressure,
3 GPa

General Purpose Decay Channel
Instrument (for Pressure Studies)

Muon Energy: 5-60 MeV (μ^+ / μ^-)



0.6 T
0.3 - 500 K
3 GPa

HAL-9500

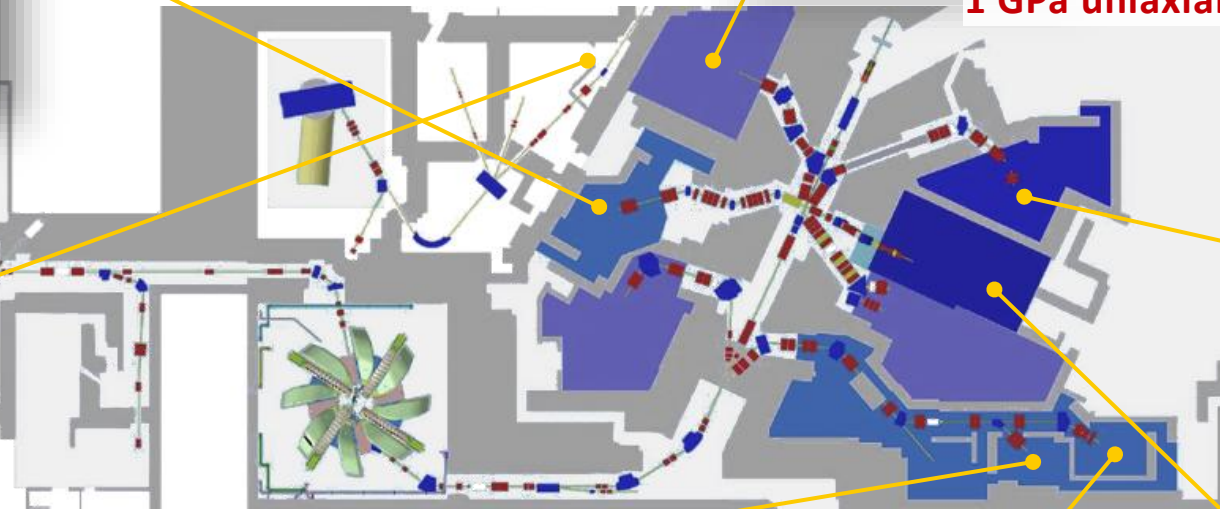
9.5 T, 10 mK

High Field and Low Temperature

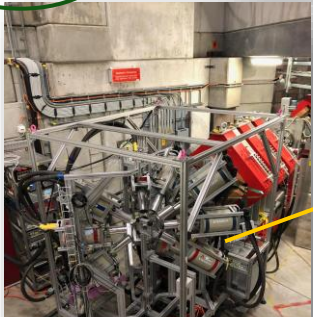
Muon Energy: 4 MeV (μ^+)



9.5 T
0.01 - 300 K
 $\Delta t \sim 60$ ps

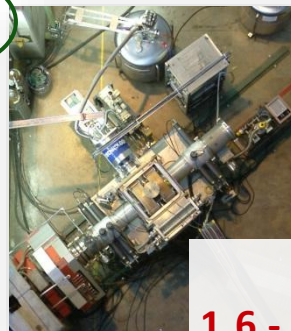


GIANT



MIXE, 1 - 15 MeV (μ^-)
elemental analysis
3 weeks per year

GPS

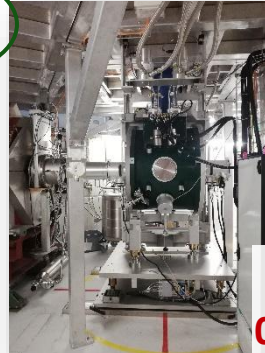


Very fast
MORE

General Purpose Surface
Muon Instrument

Shared Surface Muon Beam
Muon on Request (MORE)
Muon Energy: 4 MeV (μ^+)

FLAME



FLexible Advanced
MuSR Environment

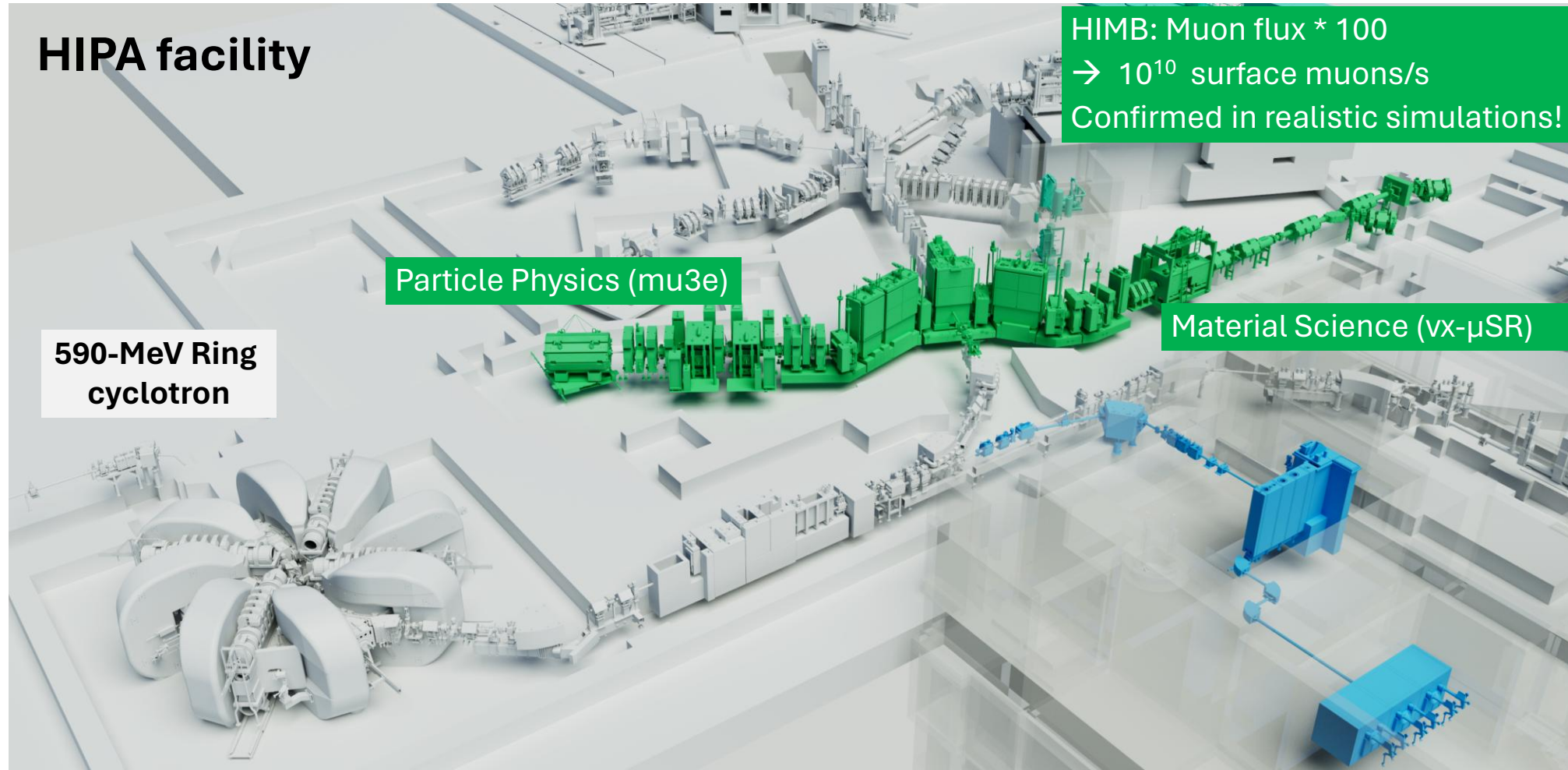
0.8 T
1.6 - 1000 K

Muon Energy:
4 MeV (μ^+)

Veto at mK
multi-sample
MORE

3.5 T
0.02 - 310 K

Getting ready for HIMB



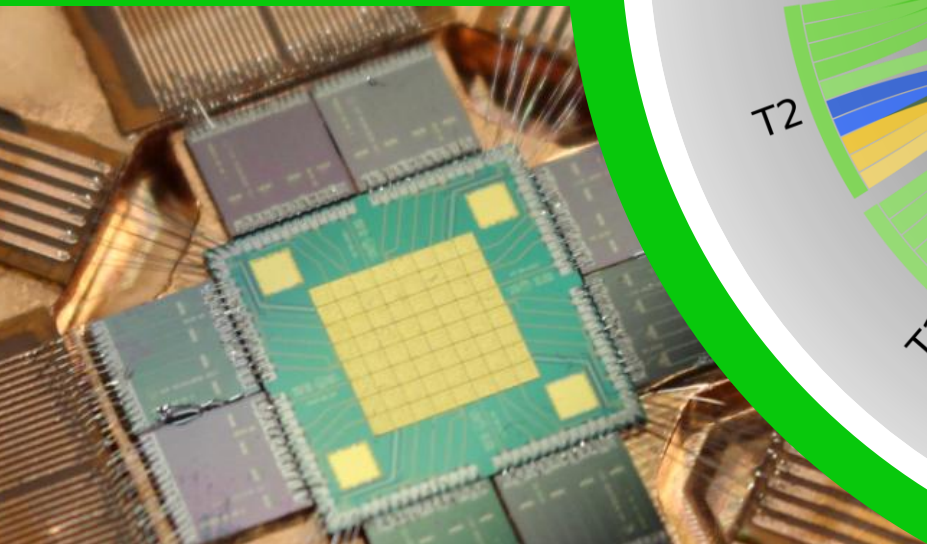
**HIMB will give us two new beamlines complemented with 5 other existing ones
Instrumentation for HIMB is simultaneously developed by CNM and partners,
in particular Muoniverse**



MUONIVERSE: A COHERENT MUON NETWORK ENABLING NEW RESEARCH AND APPLICATIONS



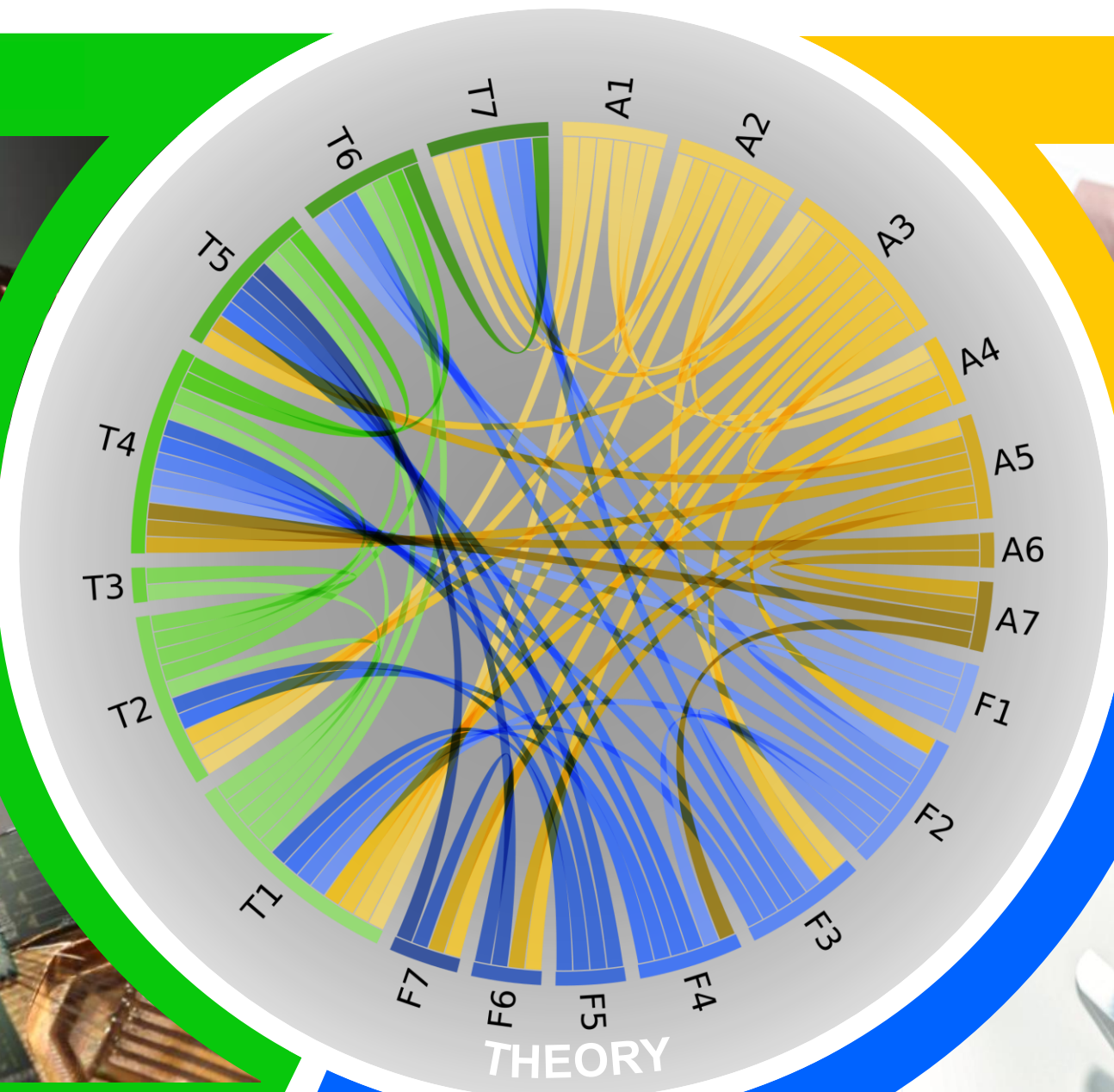
TECHNOLOGY

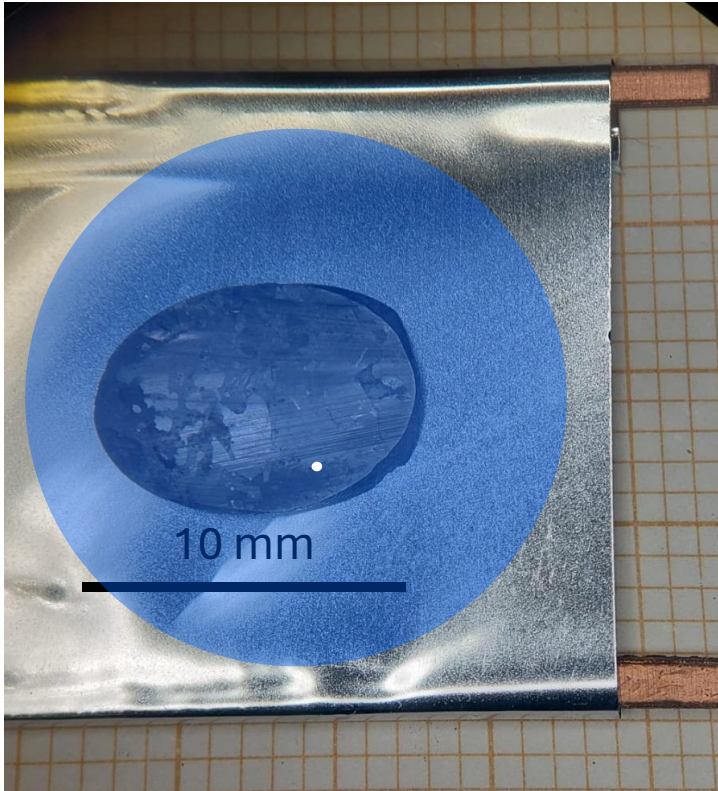


APPLICATION

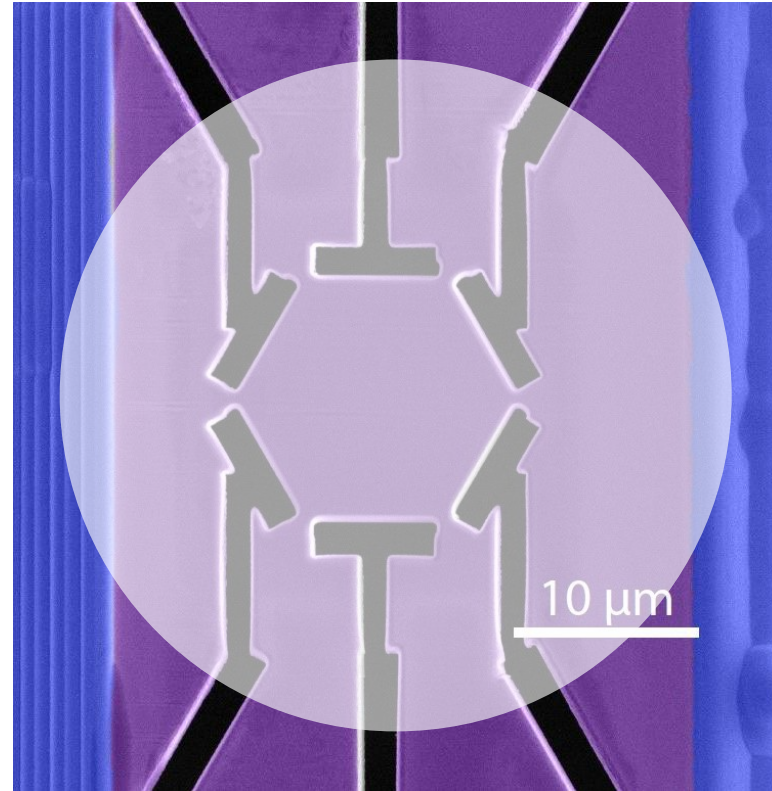


FUNDAMENTAL





Typical quantum material sample measured with μ SR



Functional quantum device cut from bulk sample, *Nat. Phys.* **20**, 579 (2024)

State of the art

Muon spectroscopy is a powerful probe of *bulk* quantum materials

Challenge

To functionalize their properties in devices and understand their performance, we need to probe 1000 times smaller structures

- + Muoniverse will drive and combine step-changes for cooled, small-size muon beams and detector resolution
- + Close collaboration between projects

KEY TECHNOLOGIES FOR MUONIVERSE



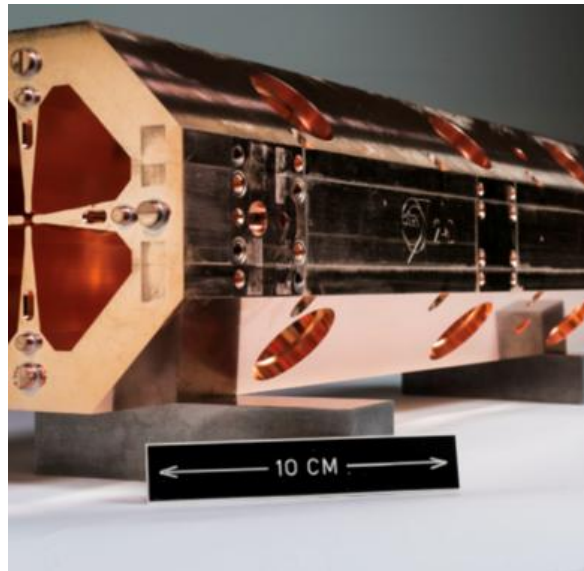
Innovative technologies beyond current scientific capabilities

- + Muoniverse projects develop novel muon beams, new types of detectors and other technologies that will redefine muon science
- + Theory and experiment work hand in hand to push boundaries in fundamental sciences and applications

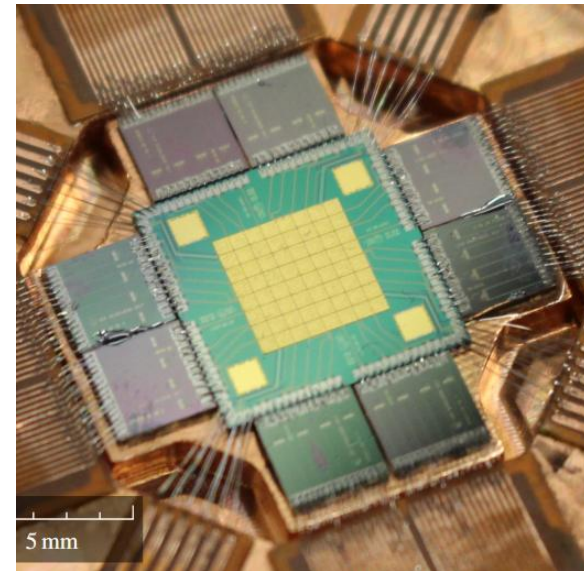
Muon production & cooling



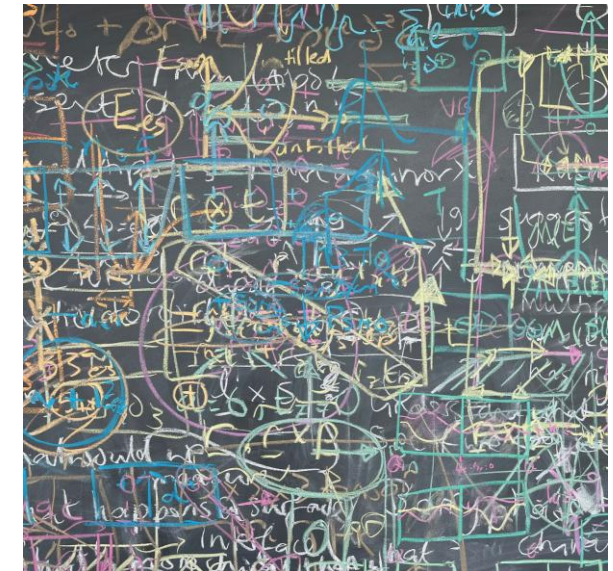
Re-acceleration



Detection



Theory & experiment



Present limitations

Lateral resolution, inaccessible implantation depth $\sim 100 \text{ nm} - 100 \text{ }\mu\text{m}$

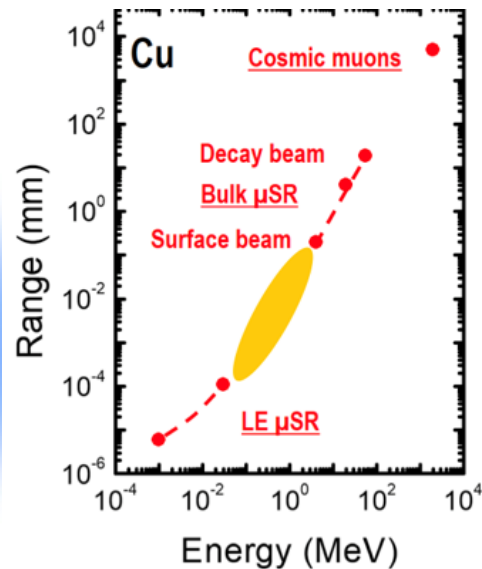
Muoniverse developments

- + Bright muon microbeams, tunable in energy, lateral resolution, multiplexing
- + Re-acceleration to multi-MeV energies for broad applications, including microscopy

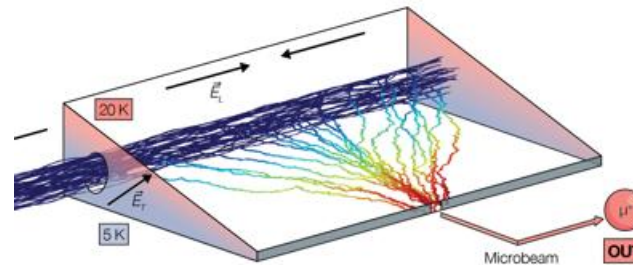
Beam size reduction



Muon range gap

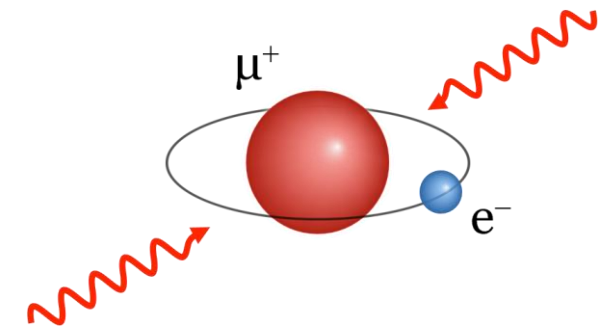


Low-energy muon cooling



Cooling improves
brightness $\times 100,000$
R&D on re-acceleration

Production of cold muonium in vacuum from thin SF-He films



Precision spectroscopy

Present limitations

Lateral resolution, rates and statistics

Muoniverse developments

+ Thin depleted monolithic active pixel sensors (DMAPS)

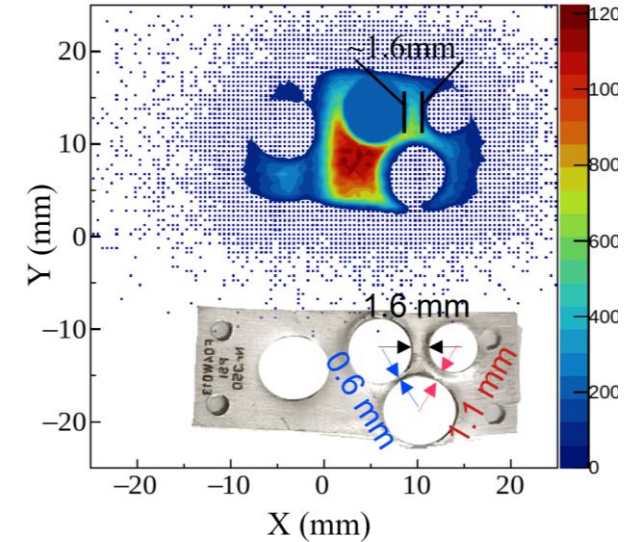
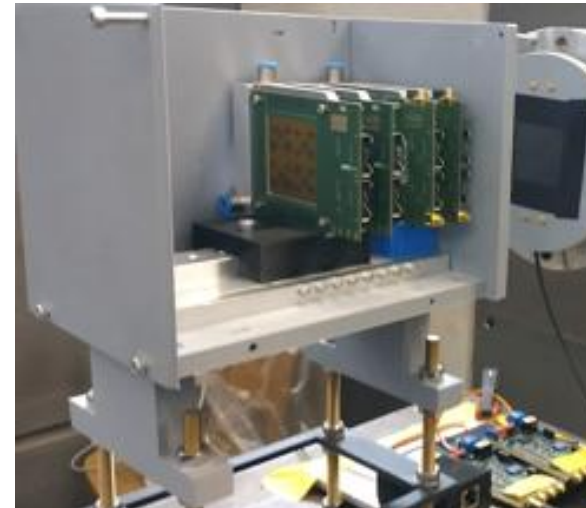
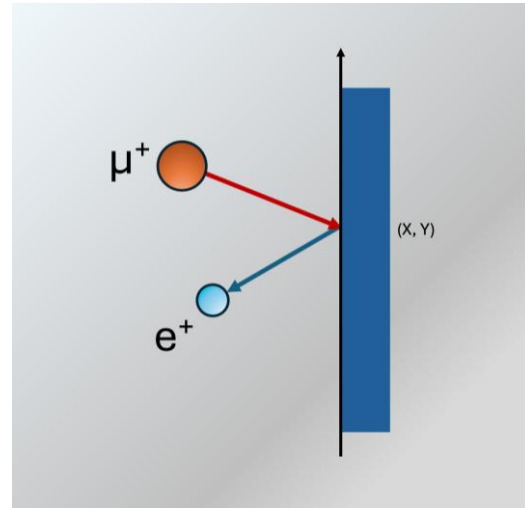
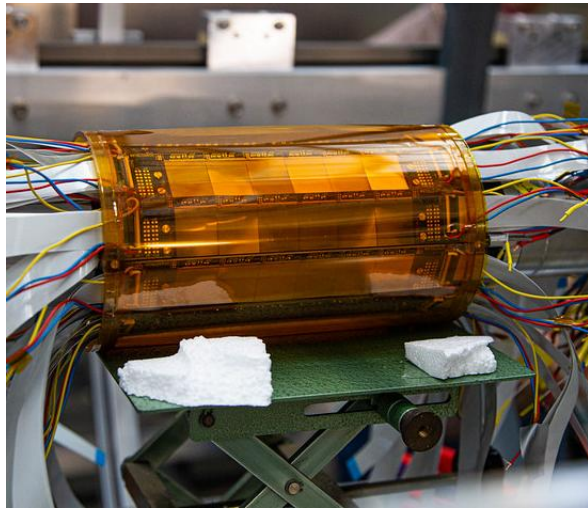
+ Muon and positron vertexing for $\sim 100 \mu\text{m}$, $\sim 100 \text{ps}$ resolution and $10\text{--}100\times$ rates

Mu3e pixel tracking detector

2D vertex reconstruction principle

μ SR vertexing test setup

2D vertex reconstruction measurement



TECHNOLOGY EXAMPLE: REVOLUTION IN BROAD-BAND MUONIC X-RAY SPECTROSCOPY



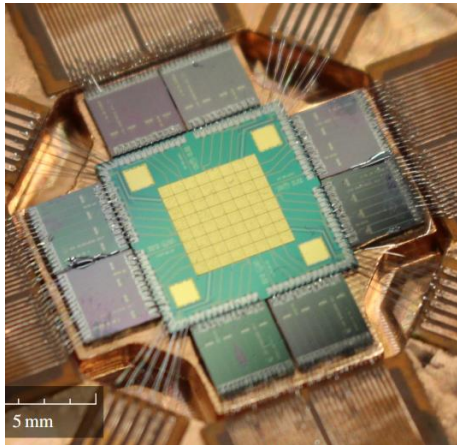
State-of-the-art spectroscopy limited by resolution at energies below a few hundred keV

MMC detectors improve resolution for muonic X-rays by an order of magnitude

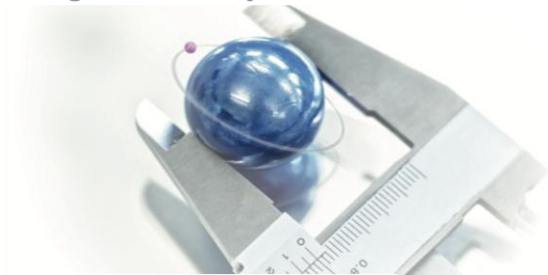
Muoniverse realizes leaps forward in

atomic and nuclear physics, and elemental analysis

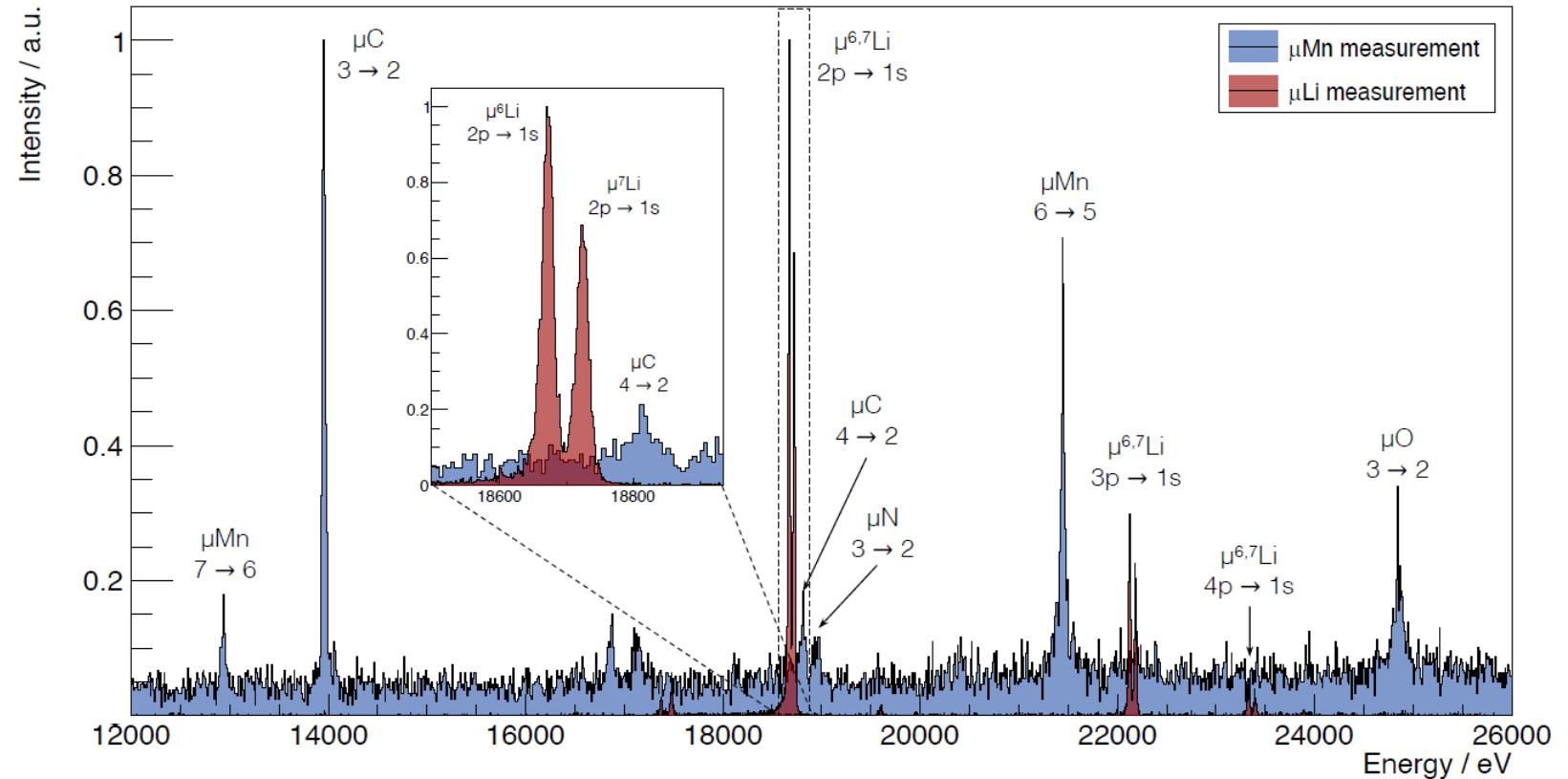
Metallic magnetic calorimeter (MMC)



Improve measurements of nuclear charge radii by an order of magnitude



Muonic X-ray test spectra (QUARTET at PSI)



MUONIVERSE IS DESIGNED TO PROMOTE COLLABORATION AND SYNERGIES



Equal opportunities, gender, diversity and inclusion

The Interdisciplinary Centre for Gender Studies at the University of Bern will consult and guide us in implementing our gender strategy based on quantitative data

Transdisciplinary communication

Through the *artists-in-labs program*, the Innovation and other platforms, and our outreach, we will learn and apply a common transdisciplinary language

Education and training

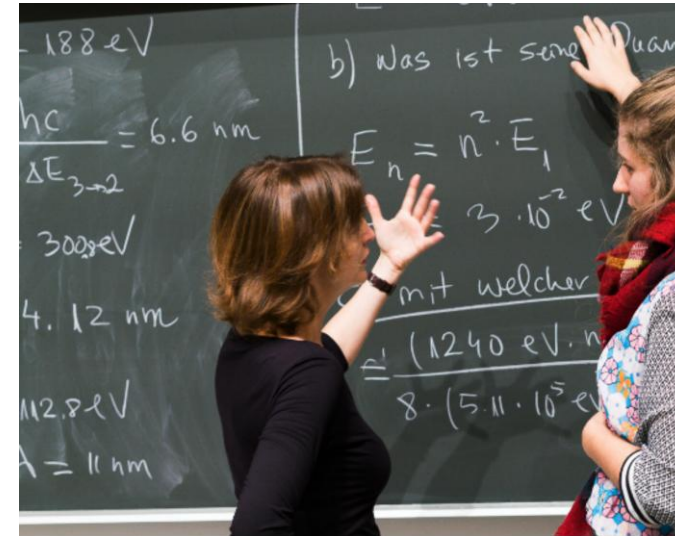
Interdisciplinary *Muoniverse Research School* for all Muoniverse PhD students

Approaches at ICGS

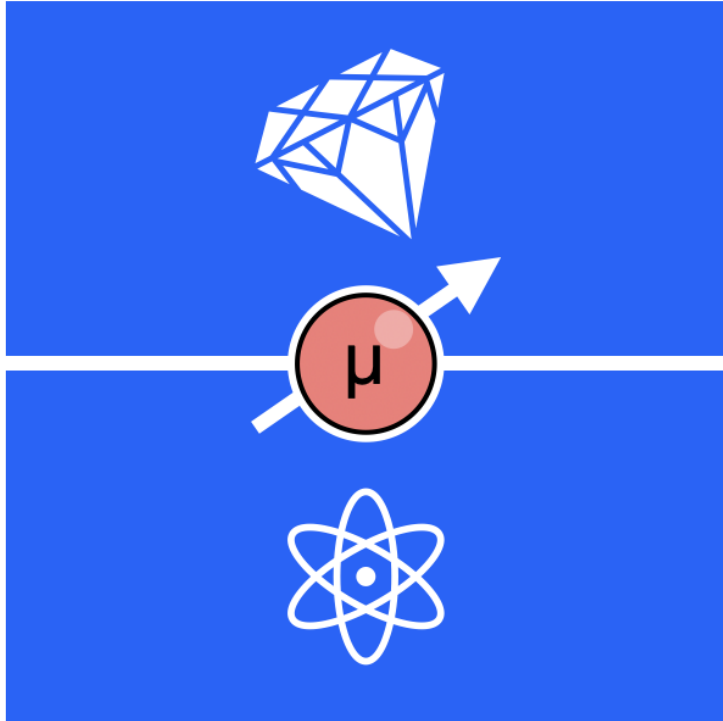
artists-in-labs program of ZHdK

Education & training

Outreach



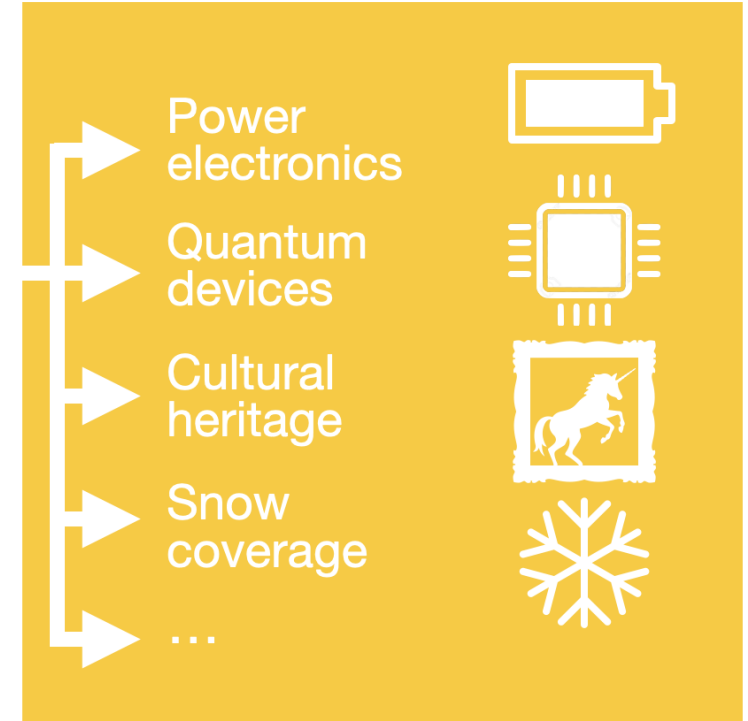
MUONIVERSE: KEY TAKEAWAYS



Muons are powerful and established probes of advanced materials and for high-precision particle physics



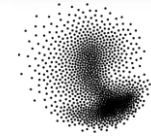
Technological developments within Muoniverse will drive a step-change in muon science



This step-change will open up the power of muons to new scientific domains and applications

Overarching goal

Muoniverse will drive a coherent, multi-disciplinary, cutting-edge muon science programme across a sustainable network of communities



PSI



THANK YOU!

- PSI is today providing low-momentum beams of muons at world-leading intensities for experiments in particle and nuclear physics and materials science
- HIMB: In a HIPA shutdown 01/2028 – 07/29, we will replace target station M by target H and implement two new high-intensity muon beams
- The NCCR Muoniverse will start May 1, 2026. It is approved for 4 years and can be extended up to 12 years. It will boost the scientific exploitation of the muon facility at PSI, but reach beyond it and create a national and international network of multi-disciplinary communities.

