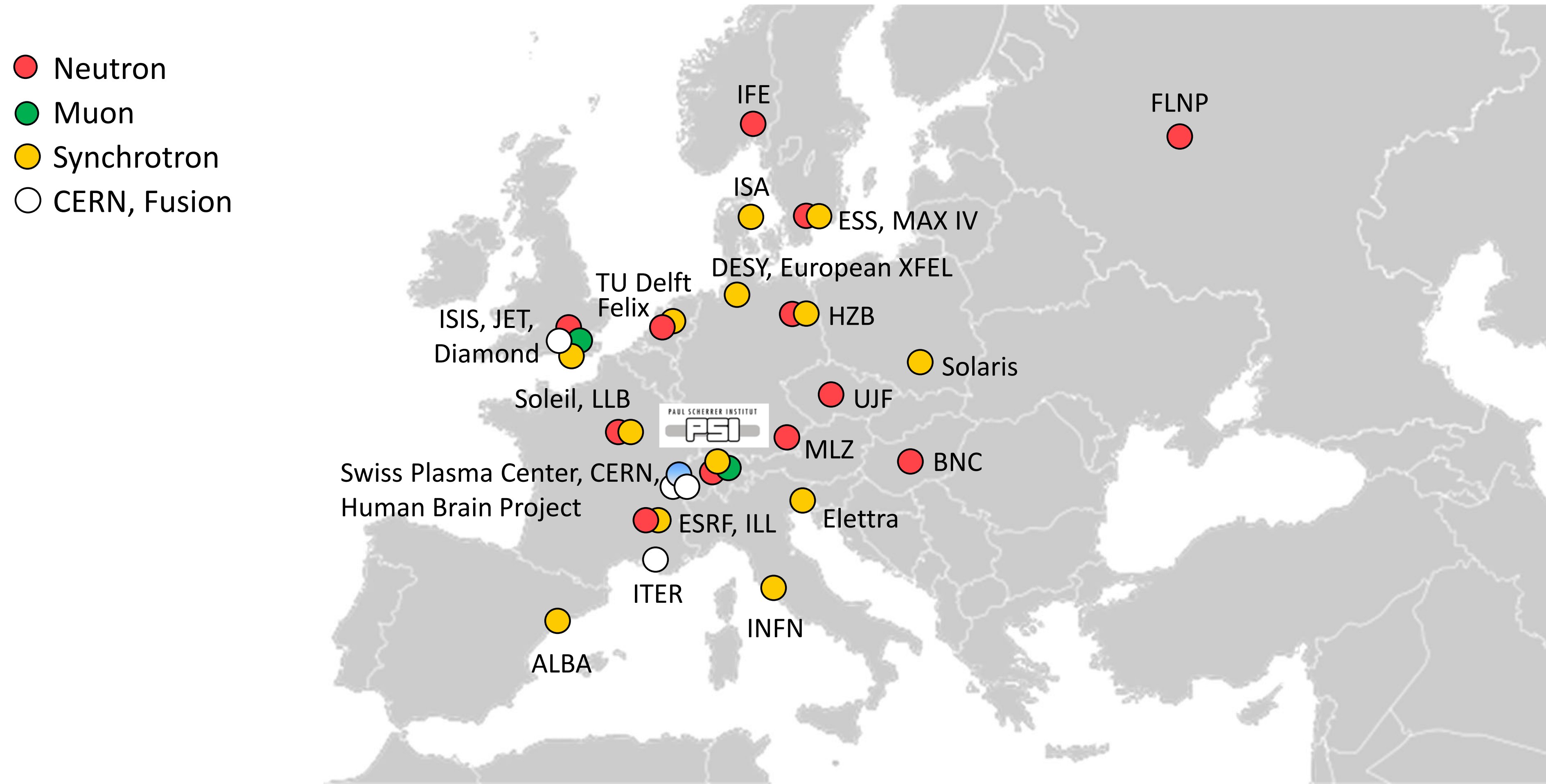
PSI/NUM and Large Scale Facilities

Alex Amato :: NUM Head a.i. :: PSI

Research facilities in Europe

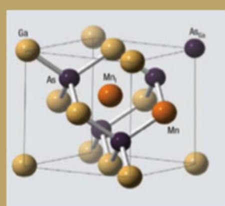


Paul Scherrer Institute – ETH Domain

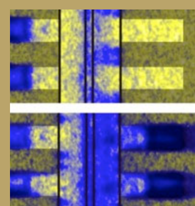
PAUL SCHERRER INSTITUT PSI

Paul Scherrer Institut – Mission

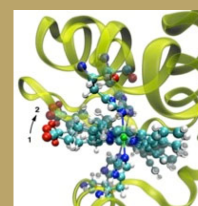
Matter and materials



Energy and environment



Human health



Development
Construction
Operation

Large research facilities

Swiss and foreign users from academia and industry

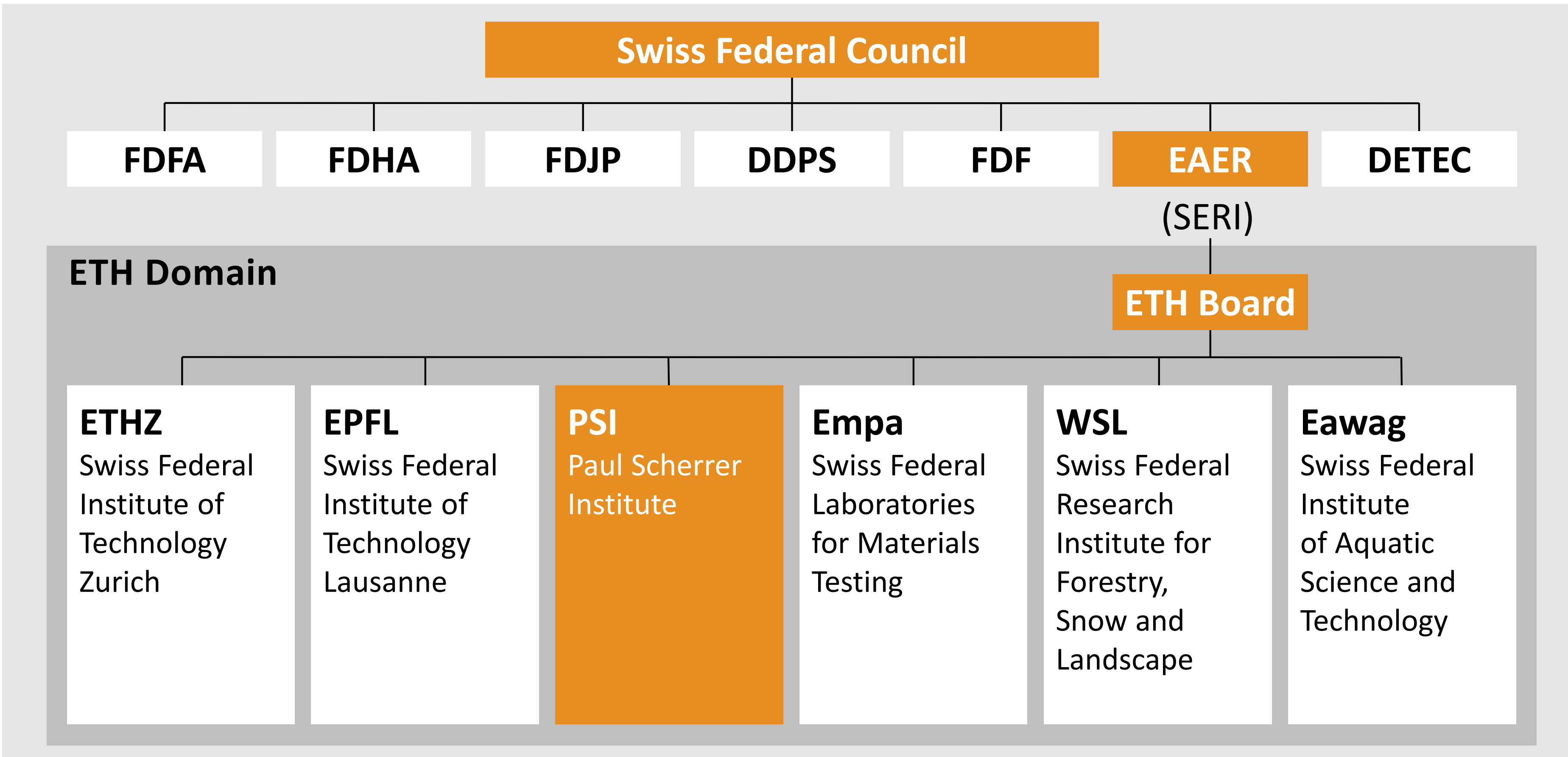
more that 2400 external users/year (38 beamports)

Knowledge & expertise

Education

Technology transfer

Political embedment



PAUL SCHERRER INSTITUT

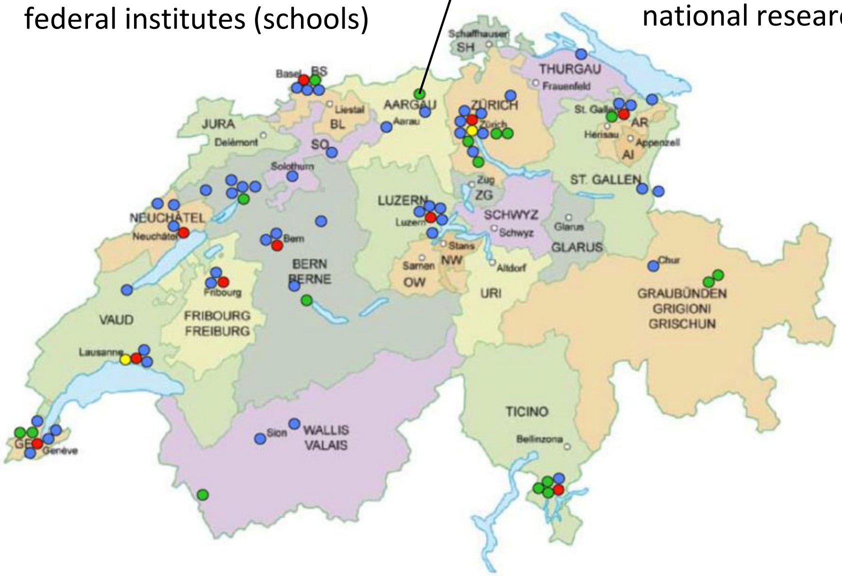
Synoptic view over Switzerland‘s university landscape

ETH Board

ETHZ	**EPFL**	**PSI**	**Empa**	**WSL**	**Eawag**
Swiss Federal Institute of Technology Zurich	Swiss Federal Institute of Technology Lausanne	Paul Scherrer Institute	Swiss Federal Laboratories for Materials Testing	Swiss Federal Research Institute for Forestry, Snow and Landscape	Swiss Federal Institute of Aquatic Science and Technology

federal institutes (schools)

national research labs



- **2 Federal Institutes of Technology** (*ETH Zurich and Lausanne*)
- **17 Federal Research Institutes**
  (among them the *four national research labs* for energy, materials, natural risks and water)
- **10 Cantonal Universities**
- **50 Universities of Applied Sciences (UAS, Fachhochschulen)**
  organized in 8 regional clusters
  (seven are public, one is a Public-Private Partnership, PPP)

ETH DOMAIN

THE FOUR RESEARCH INSTITUTIONS IN NUMBERS…

736 Mio CHF Budget

521 Mio CHF Public (Base) Funding

118 Mio CHF Science Funding by Agencies

97 Mio CHF Contracts with Industry Partners

151 Professors

79 at ETHZ + EPFL
38 at Swiss Universities
34 at Universities abroad

3923 Employees

1945 Scientists
1474 Technical Staff
504 Admin Staff

1423 People in Education

842 PhD students
399 Postdocs
182 Apprentices

18553 Hours in Teaching and Practical Training

Large Research and TT Facilities

SLS, SwissFEL, SINQ, SμS, CHRISP, ESI, NEST, move

National Tasks*

National Forest Inventory, National Air Pollution Monitoring Network, Ecotox Centre, Center for Proton Therapy at PSI (CPT)

13 Sites in 9 Cantons

AG, BE, GR, LU, SG, TI, VD, VS, ZH

*only a representative selection

1652 externally funded Science Projects

483 from SNF
215 from EU
94 Innosuisse
860 from other sources

2741 Contracts with Industry Partners

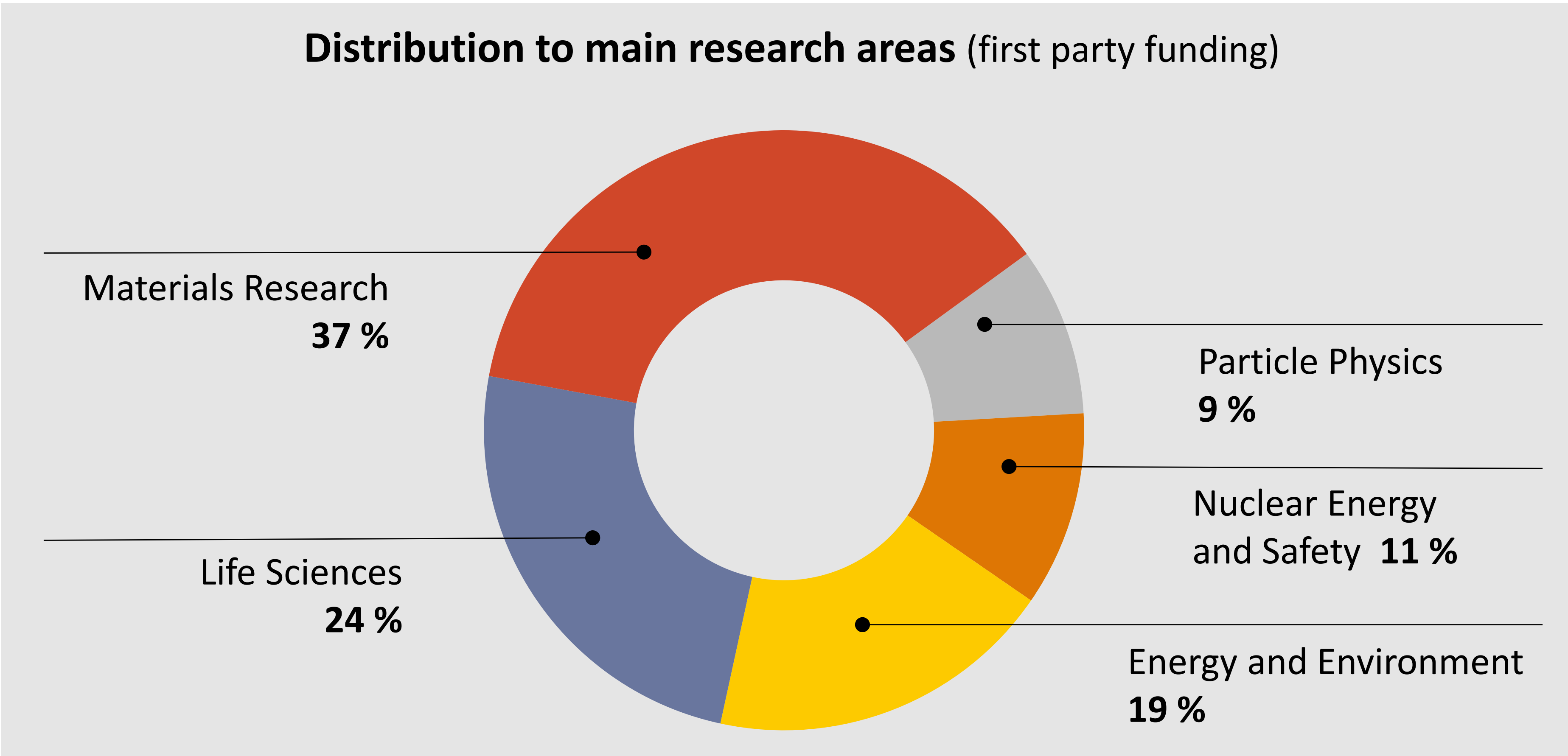
352 Research Projects
242 Licences
2147 Customer Orders and Scientific Services

Paul Scherrer Institute – ETH Domain

ETHZ	EPFL	PSI	Empa	WSL	Eawag
Swiss Federal Institute of Technology Zurich	Swiss Federal Institute of Technology Lausanne	Paul Scherrer Institute	Swiss Federal Laboratories for Materials Testing	Swiss Federal Research Institute for Forestry, Snow and Landscape	Swiss Federal Institute of Aquatic Science and Technology

PSI funds (global budget)	300	MCHF
External funding	110	MCHF
Staff (PSI and affiliated on campus)	2500	
• Professors at ETHZ, EPFL, universities	65	
• Engineers and technicians	1000	
• Postdocs, PhD students, apprentices	720	
External users: people / visits	2400 / 4900	per year
Number of scientific publications	1400 (13 % high impact)	per year
Patient visits (proton therapy treatment)	5700	per year

Budget


Distribution to main research areas (first party funding)
Materials Research
37 %
Life Sciences
24 %
Particle Physics
9 %
Nuclear Energy
and Safety 11 %
Energy and Environment
19 %

NUM in a nut shell

PAUL SCHERRER INSTITUT

Research Committee	Prof. Dr. Marco Stampanoni	1100
Human Resources Management	Karsten Bugmann	1300
Center for Proton Therapy	Prof. Dr. Damien Weber	1700
Quantum Criticality and Dynamics	Prof. Dr. Christian Rüegg i.P.	1001

Director
Prof. Dr. Christian Rüegg
1000

Members of the board of directors:
Prof. Dr. Gabriel Aeppli*
Dr. Peter Allenspach
Prof. Dr. Andreas Pautz
Prof. Dr. Gebhard F. X. Schertler
Prof. Dr. Thomas J. Schmidt
Prof. Dr. Mike Seidel
Dr. Thierry Strässle*

Directorate Support	Dr. Thierry Strässle	1100
Human Resources Management	Karsten Bugmann	1300
Safety	Dr. Werner Roser	1100
Communications	Dr. Mirjam van Daalen	1100
Science	Dr. Ines Günther-Leopold Dr. Michèle Erat	1100
Finance and Administrative Services	Dr. Frank Behner	1100
Technology Transfer	John Millard	1110

Research Division
Biology and Chemistry (BIO)
Prof. Dr. Gebhard Schertler
2000

Research Division
Research with Neutrons and Muons (NUM)
Dr. Alex Amato a.i.
3000

Research Division
Nuclear Energy and Safety (NES)
Prof. Dr. Andreas Pautz
4000

Research Division
Energy and Environment (ENE)
Prof. Dr. Thomas J. Schmidt
5000

Research Division
Photon Science (PSD)
Prof. Dr. Gabriel Aeppli
6000

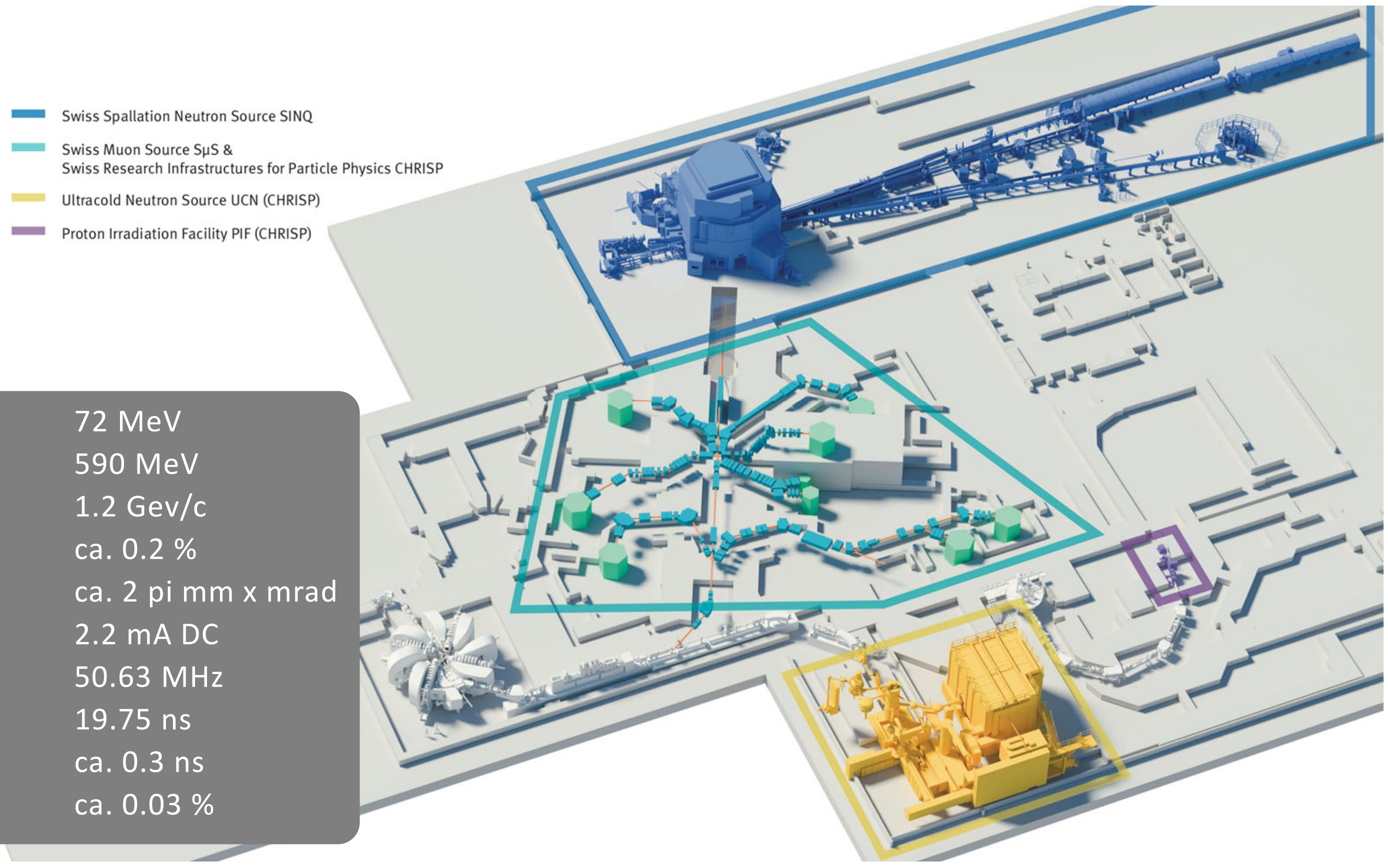
Research Division
Scientific Computing, Theory and Data (SCD)
Prof. Dr. Christian Rüegg a.i.
7000

Division
Large Research Facilities (GFA)
Prof. Dr. Mike Seidel
8000

Division
Logistics (LOG)
Dr. Peter Allenspach
9000

NUM in a nut shell

- Responsible for the **operation, development, and scientific exploitation** of the **neutron and muon instrumentation** around the High Intensity Proton Accelerator (HIPA)



Injection Energy	72 MeV
Extraction Energy	590 MeV
Extraction Momentum	1.2 Gev/c
Energy spread (FWHM)	ca. 0.2 %
Beam Emittance	ca. 2 pi mm x mrad
Beam Current	2.2 mA DC
Accelerator Frequency	50.63 MHz
Time Between Pulses	19.75 ns
Bunch Width	ca. 0.3 ns
Extraction Losses	ca. 0.03 %

PAUL SCHERRER INSTITUT PSI

NUM in a nut shell

PAUL SCHERRER INSTITUT PSI

Research Division

Research with Neutrons and Muons (NUM)

Dr. A. Amato a.i.
3000

Deputy Head of Division	Prof. Dr. M. Janoschek a.i.	3600
Division Representation Technology Transfer	A. Sozzi	1110
HR Management	S. Minniti	1320
Divisional Financial Management	M. Kornilova	9102

PSI User Office	Dr. S. Janssen	3001

Particle Physics (LTP)
Prof. Dr. K. Kirch (ETHZ)
3200

- **Particle Physics Theory** – Prof. Dr. A. Signer (Uni ZH) – 3201
- **High Energy Particle Physics** – Prof. Dr. L. Caminada – 3202
- **Muon Physics** – Dr. S. Ritt – 3203
- **UCN Physics** – Dr. B. Lauss – 3204
- **Electronics for Measuring Systems** – U. Greuter – 3205
- **Detectors, Irradiation, Applied Particle Physics** – Dr. M. Hildebrandt – 3206
- **Electronics Vocational Training and Service Pool** – C. Kämpf a.i. – 3208

Neutron Scattering and Imaging (LNS)
Prof. Dr. M. Kenzelmann
3300

- **Solid State Structures** – Dr. J. White – 3301
- **Solid State Dynamics** – Prof. Dr. M. Kenzelmann a.i. – 3302
- **Soft Matter** – PD Dr. U. Gasser – 3303
- **Applied Materials** – Prof. Dr. M. Strobl – 3304

Muon Spin Spectroscopy (LMU)
Dr. T. Prokscha a.i.
3500

- **Bulk-μSR** – Dr. H. Luetkens – 3501
- **Low Energy Muons** – Dr. T. Prokscha – 3502

Neutron and Muon Instrumentation (LIN)
Prof. Dr. M. Janoschek
3600

- **Sample Environment** – Dr. M. Bartkowiak – 3601
- **Operation of Spallation Sources** – Dr. B. Blau – 3602
- **Mechanical and Electrical Engineering** – P. Keller – 3603
- **Neutron Optics and Scientific Computing** – Dr. U. Filges – 3604
- **NUM Vocational Training and Service Pool** – Dr. Y. Müller – 3605

Multiscale Materials Experiments (LMX)
Prof. Dr. T. Lippert
3700

- **Mesoscopic Systems** – Prof. Dr. L. Heyderman (ETHZ) – 3701
- **Thin Films and Interfaces** – Prof. Dr. T. Lippert i.P. – 3702
- **Solid State Chemistry** – Dr. E. Pomjakushina – 3703
- **Physical Properties of Materials** – Dr. M. Medarde – 3704

CHRISP

SINQ

SμS

Engineering

Functional Materials & Devices

Measurements Platforms

PAUL SCHERRER INSTITUT

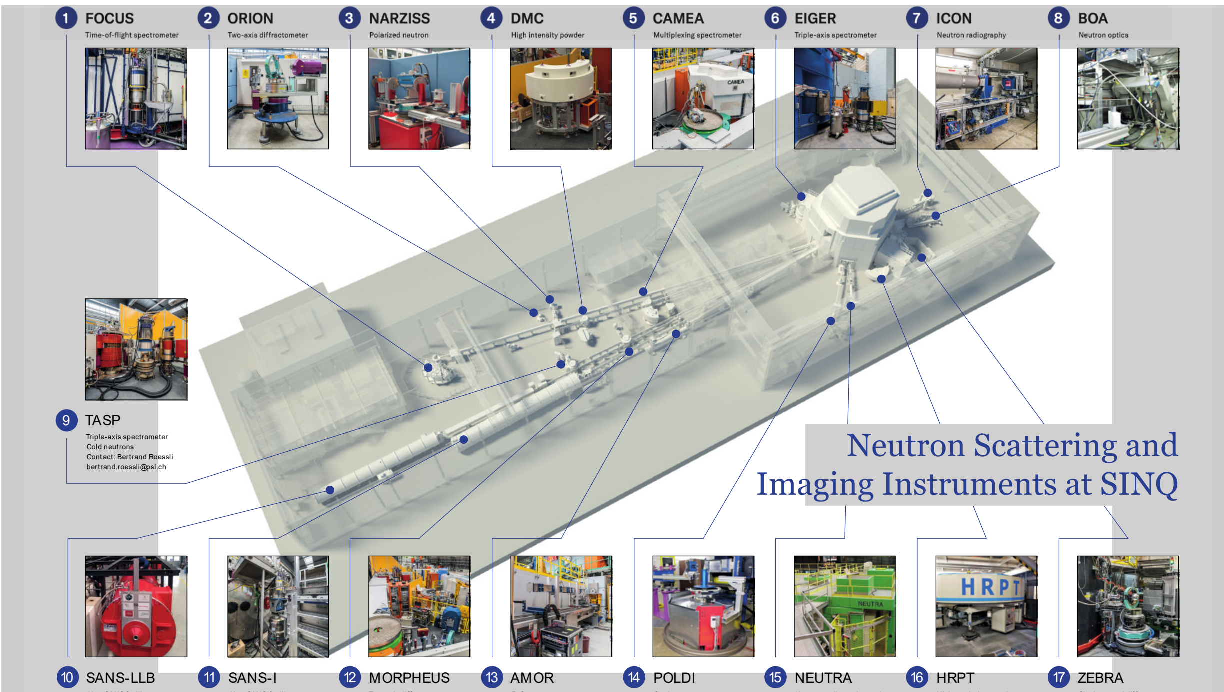
NUM „Head Count“ (2022)

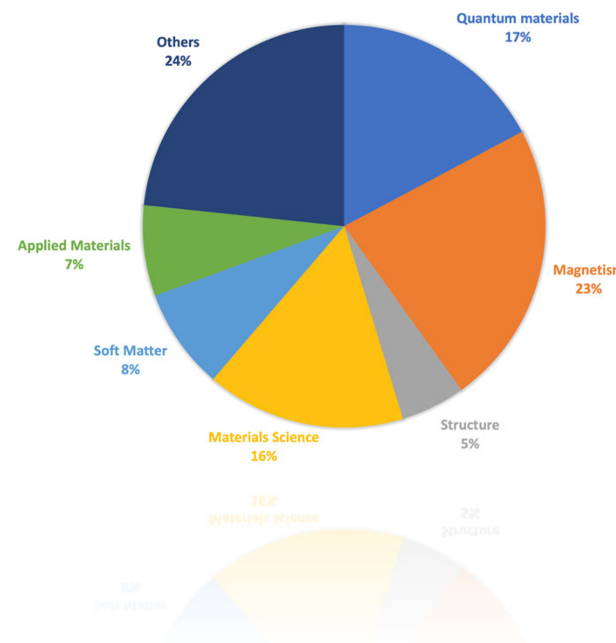
Units	**Headcount**	**FTEs**
NUM staff + U.O.	10	8.2
LTP	65	61.0
LNS	47	45.4
LMU	19	19.0
LIN	45	43.0
LMX	30	29.9
Total NUM	**216**	**206.5**

and in addition about 31 FTEs based at PSI from associated research institutions

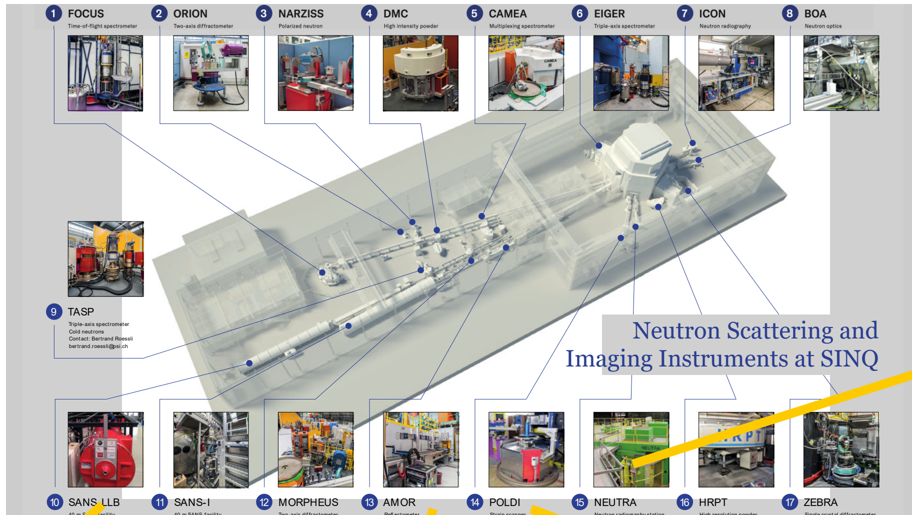
PAUL SCHERRER INSTITUT PSI

SINQ



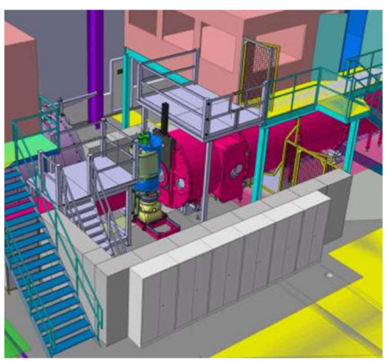


SINQ -- Upgrades



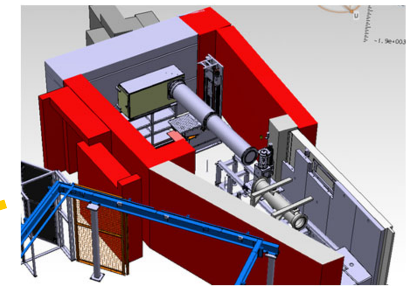
SANS-LLB

Order of magnitude of performance increase (over SANS-II) for soft matter



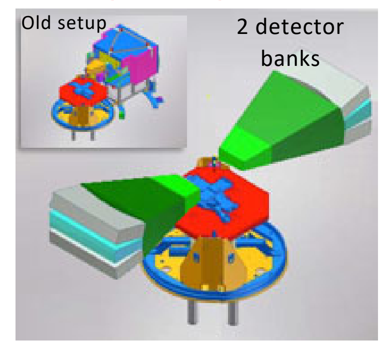
NEUTRA

Higher flexibility: Access to higher flux positions and use of higher resolution detectors



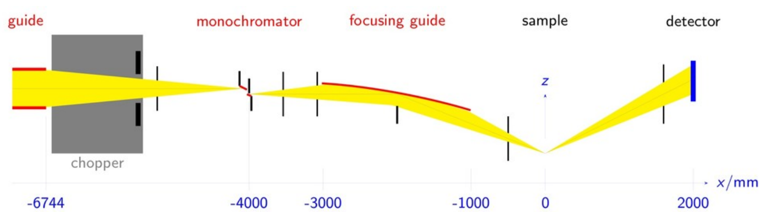
POLDI

5x performance increase for engineering diffraction



Novel reflectometer AMOR

Orders of magnitude of performance increase for growing field of thin films/ heterostructures



PAUL SCHERRER INSTITUT PSI

SμS

DOLLY

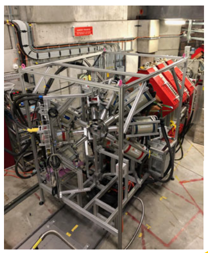
Muon Energy: **4 MeV** (μ^+)

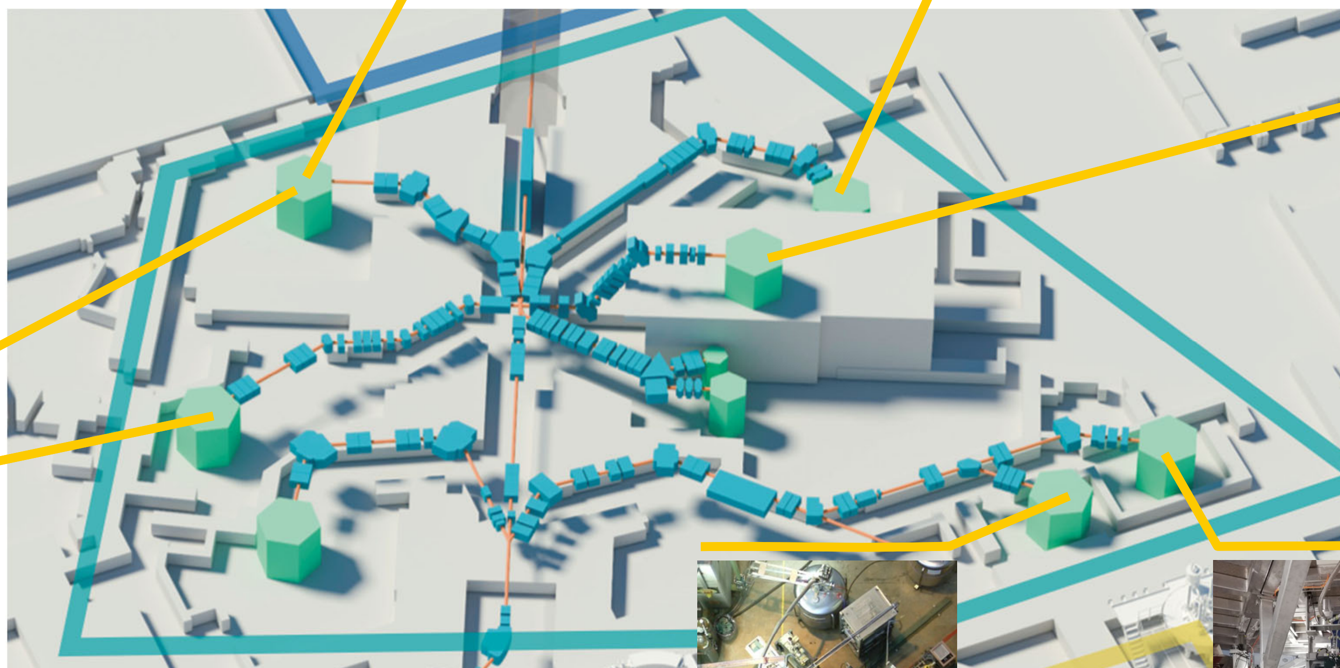
GPD

Muon Energy: **5-60 MeV** (μ^+/ μ^-)

MIXE/GIANT

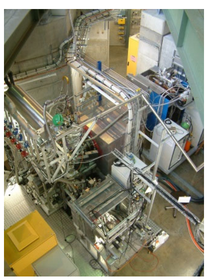
Muon Energy: **2-11 MeV** (μ^-)





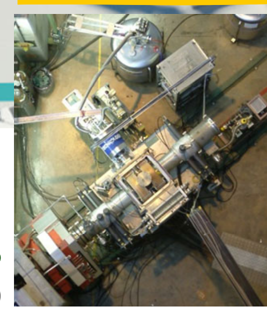
HAL-9500

Muon Energy: **4 MeV** (μ^+)



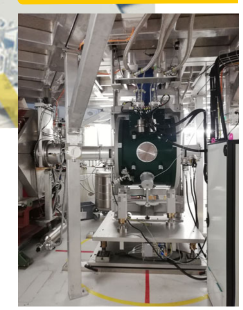
LEM

Muon Energy: **1 - 30 keV**



GPS

Muon Energy: **4 MeV** (μ^+)

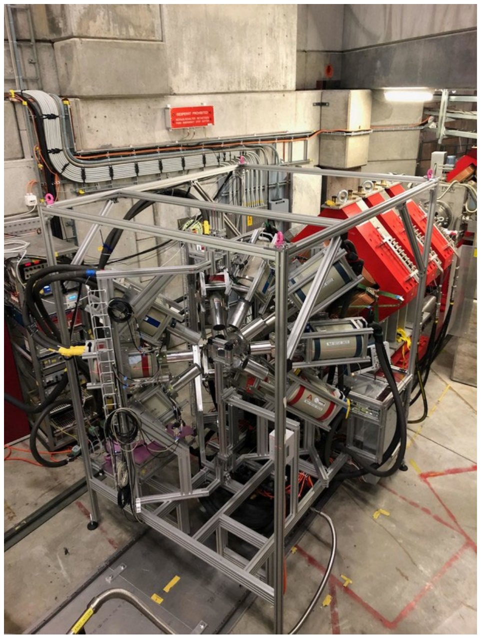


FLAME

Muon Energy: **4 MeV** (μ^+)

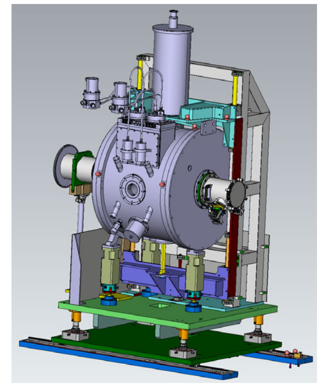
SμS -- Upgrades 1/2

MIXE Setup (GermanIum array for nondestructive testing “GIANT”)

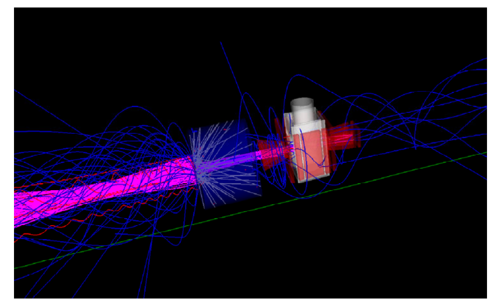


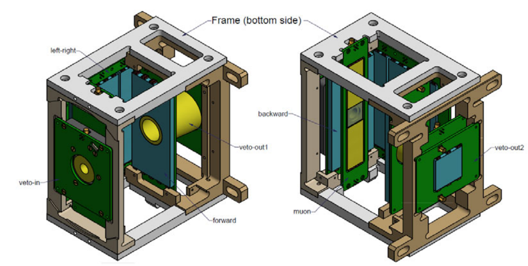
- Reproducible
- Automatic LN2 refill
- 5 min sample change
- Max 8 freely rotating arms
- Max 4 BigMac HPGe per arm
- Digitizer 16Kanal, 2V/5V, 250 MSPS, 14-bit, 128 MSample/Kanal, MAW filter, (Struck SIS3316-250-14 VME)

FLexible Advanced MuSR Environment (FLAME)



- DR stick insert (T = 25 mK – 300K)
- Warm bore 3,5 T SC, cryogen free
- Zero field B < 5 μT
- 10 ppm homogeneity, XYZ shim coils
- XYZ SC vector magnets (20 mT)
- Plastic scintillators with SiPM readout
- Active forward / backward vetos
- Time resolution: 160 ps
- Minimal sample size: 2x2 mm^2
- Minimal sample mass: >12 mg

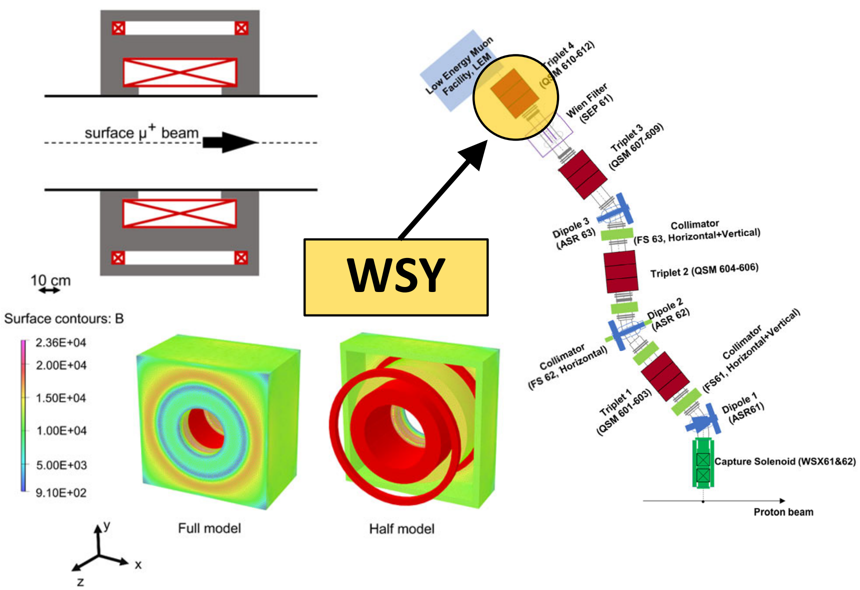




SμS -- Upgrades 2/2

LEM upgrade "Super μE4"

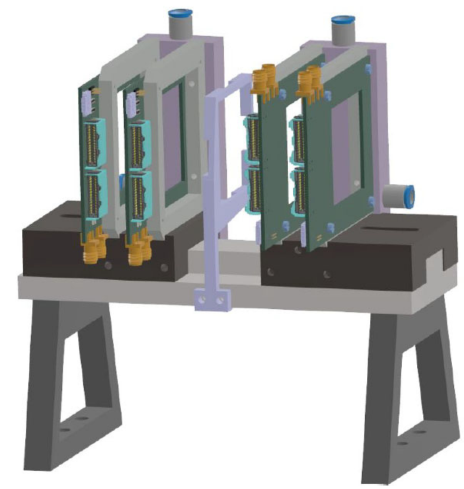
- Upgrade μE4 beamline in 2025/2026 to increase LEM rate by 50%: smaller samples, higher external stimuli (illumination, electric fields), faster measurements, T_{min} = 100 mK (2.5 K now).
- Phys. Rev. AB 25, 051601 (2022), **minimum fringe fields in LEM**
- Delivery of all magnet parts by beginning of 2024

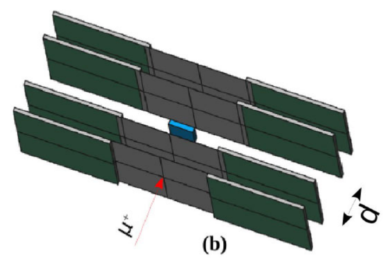


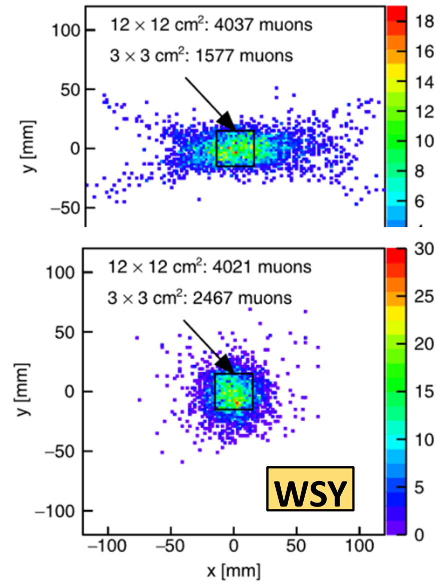
Vertex reconstruction using Si pixel detectors

Prototype test beam time in September 2023

- 4x4 MuPix11 chips (Heidelberg)
- 50 μm thin silicon chip on Kapton foil (preserves spatial resolution <1mm)
- Variable distance to confirm simulations
- Time resolution at the moment about 15ns (goal: <500ps)



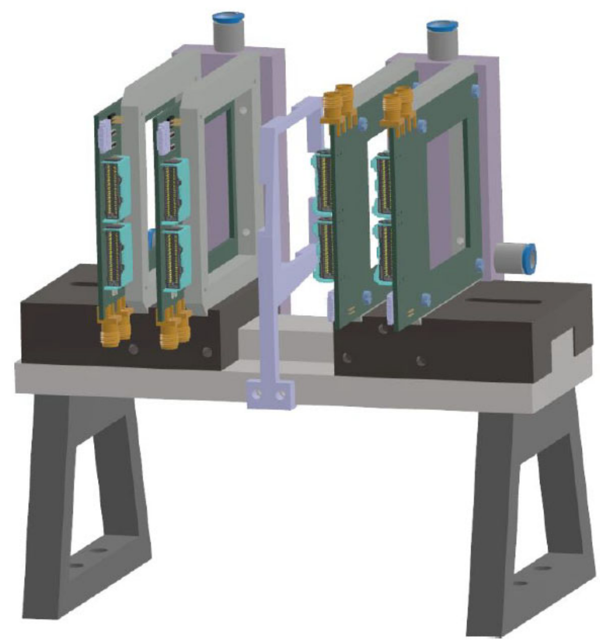


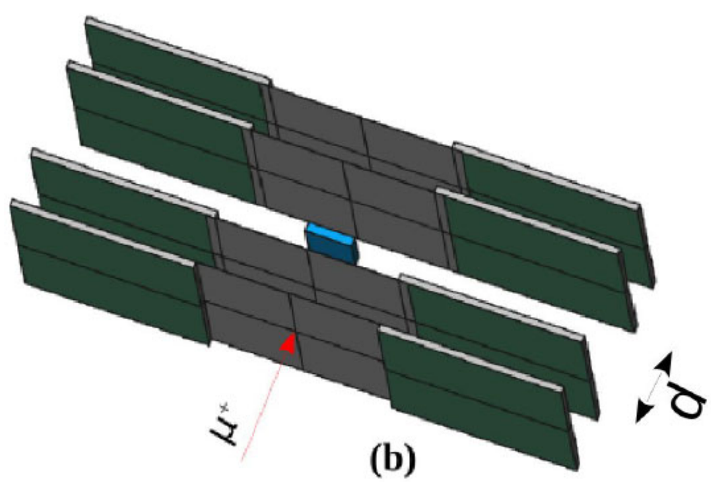

12 × 12 cm²: 4037 muons
3 × 3 cm²: 1577 muons
12 × 12 cm²: 4021 muons
3 × 3 cm²: 2467 muons
WSY
y [mm]
x [mm]

SμS -- Vertex reconstruction using Si pixel detectors

Prototype test beam time in September 2023

- 4x4 MuPix11 chips (Heidelberg)
- 50 μm thin silicon chip on Kapton foil (preserves spatial resolution <1mm)
- Variable distance to confirm simulations
- Time resolution at the moment about 15ns (goal: <500ps)

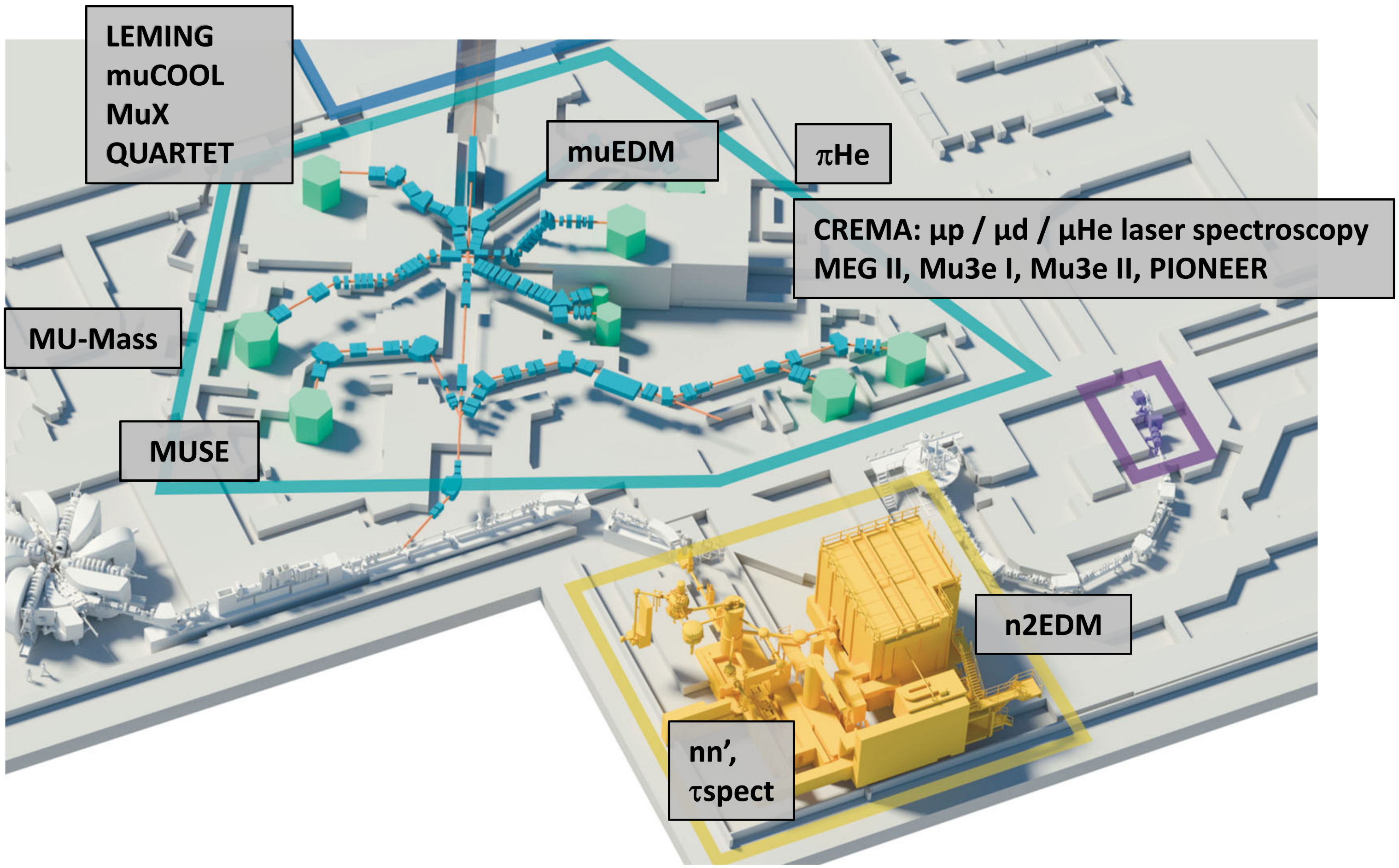




Courtesy of T. Rudzki and Z. Salman

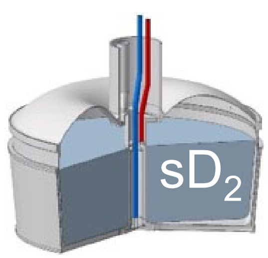
CHRISP: intensity frontier with pions, muons, UCN

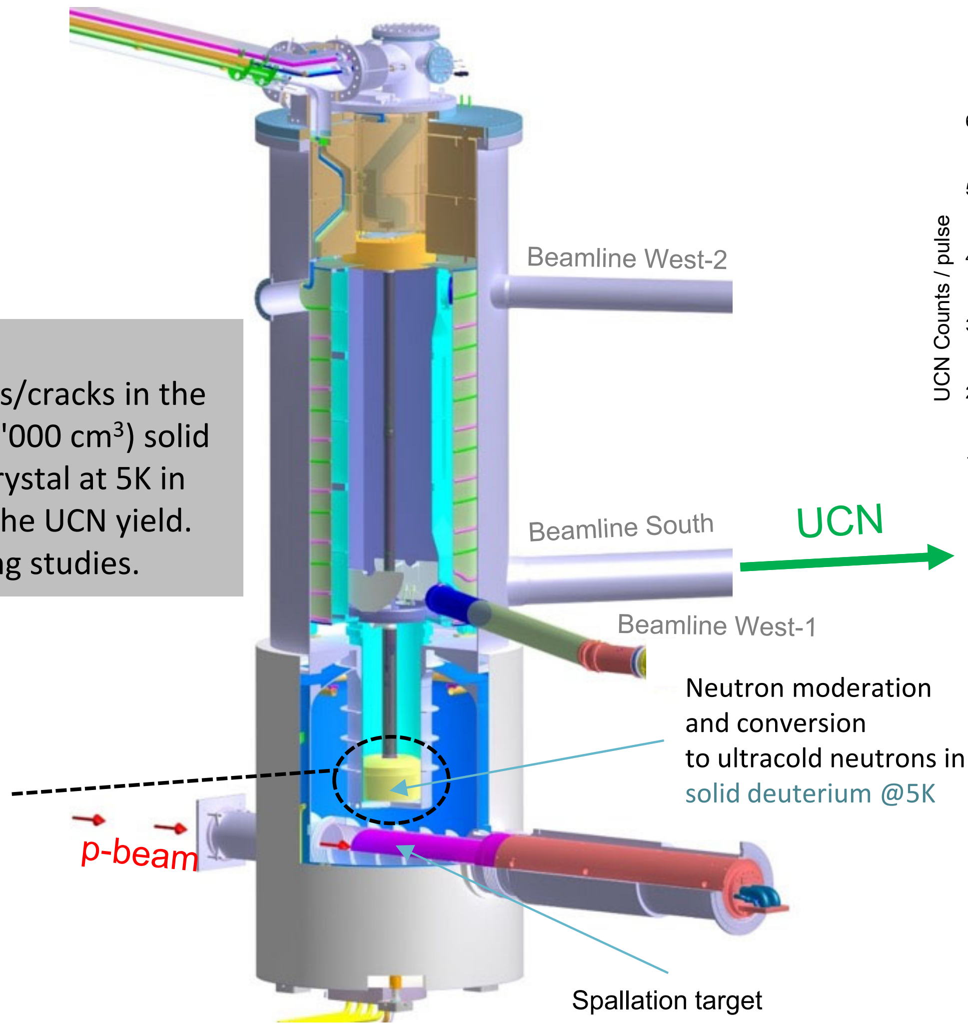
Precision experiments with **the lightest unstable particles** of their kind

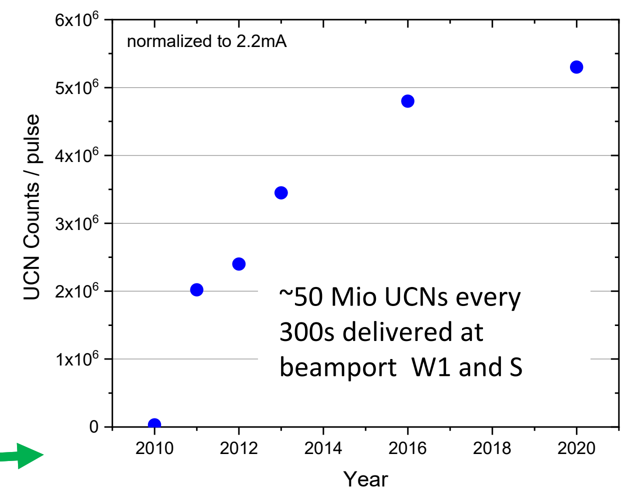


CHRISP -- High intensity Ultracold Neutron Source

Challenge:
Reduction of defects/cracks in the world's largest (~30'000 cm^3) solid deuterium (poly-) crystal at 5K in order to maximize the UCN yield.
→ Longterm freezing studies.



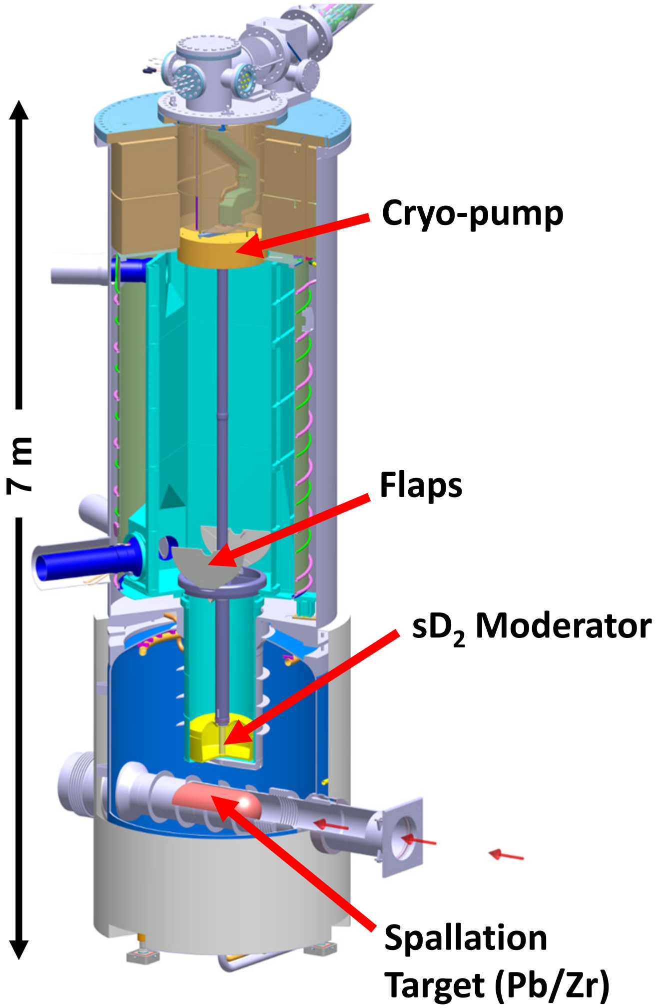




UCN intensity world-leading in comparison with other sources [Phys.Rev.C 95 (2017) 045503]

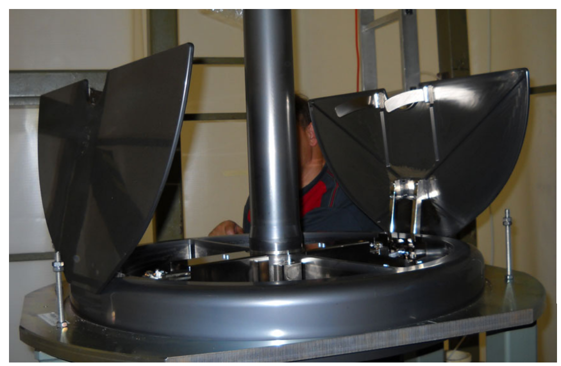
Fall 2021: + 10% average UCN output with new method of thermal treatment of solid D_2

UCN – Present Situation



Situation after 12 years of operation:

- ☹ One of the two central flaps is defective, causing a large He leak into the storage volume. The flap remains permanently closed!
- ☹ The second central flap is already showing a small He leak.
- ☹ The sD_2 moderator container has developed a cold leak through which helium flows into the vacuum of the storage volume.



Project: EZE (Ersatz Zentral Einschub)

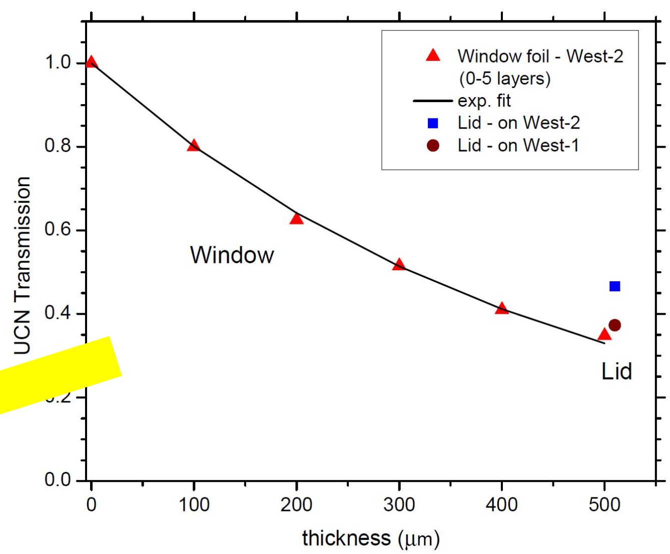
Projekt EZE

Major NUM Project in NUM: 'L-Project'

Budget: about 1.55 Mio CHF

start: 01.01.2023

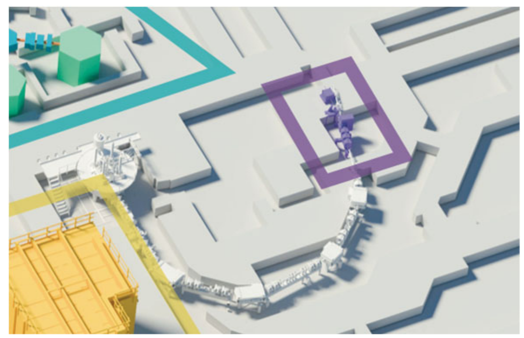
end: 2027

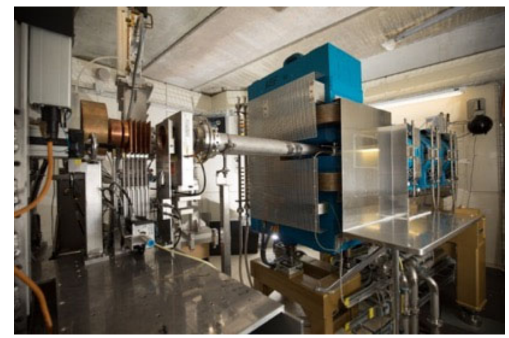


Proton Irradiation Facility PIF

Main functions:

- user-lab for studies of radiation effects
- realistic simulator of space radiation environment
- source of mono-energetic particles
- radiation qualification of space technologies
- calibration of detectors
- application oriented and user-friendly facility
- part of ESA "European Component Irradiation Facilities ECIF"





Main parameters:

- proton energy range: 6 – 230 MeV
- proton flux range: $10^2 – 10^9$ p/s/cm^2
- Gaussian-like profiles (FWHM 9 cm)
- options: focused (6mm) or flat beam profiles

Operation and User:

- ~120 test days/y with ~60 experiments/y
- ~150 visitors/y from about 40 institutions: research institutes, universities, aerospace and electronic industry from CH, EU, CHN and US
- main users: ESA and CERN

European Spallation Source - ESS

Accelerator

Target

Moderators

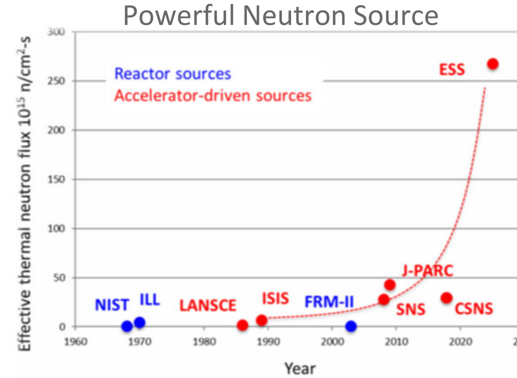
Large Scale Project:

Building cost ~3 Mrd. €

30% In-kind Contributions:

130 Institutes, 13 Partner Countries:

Powerful Neutron Source



Swiss Contribution:

165 Mio. CHF (~3.5%)

34 Mio. CHF of that at PSI – multiple divisions involved (lead NUM)

COVID →

2021 Re-Baselining

Beam on Target

groundbreaking

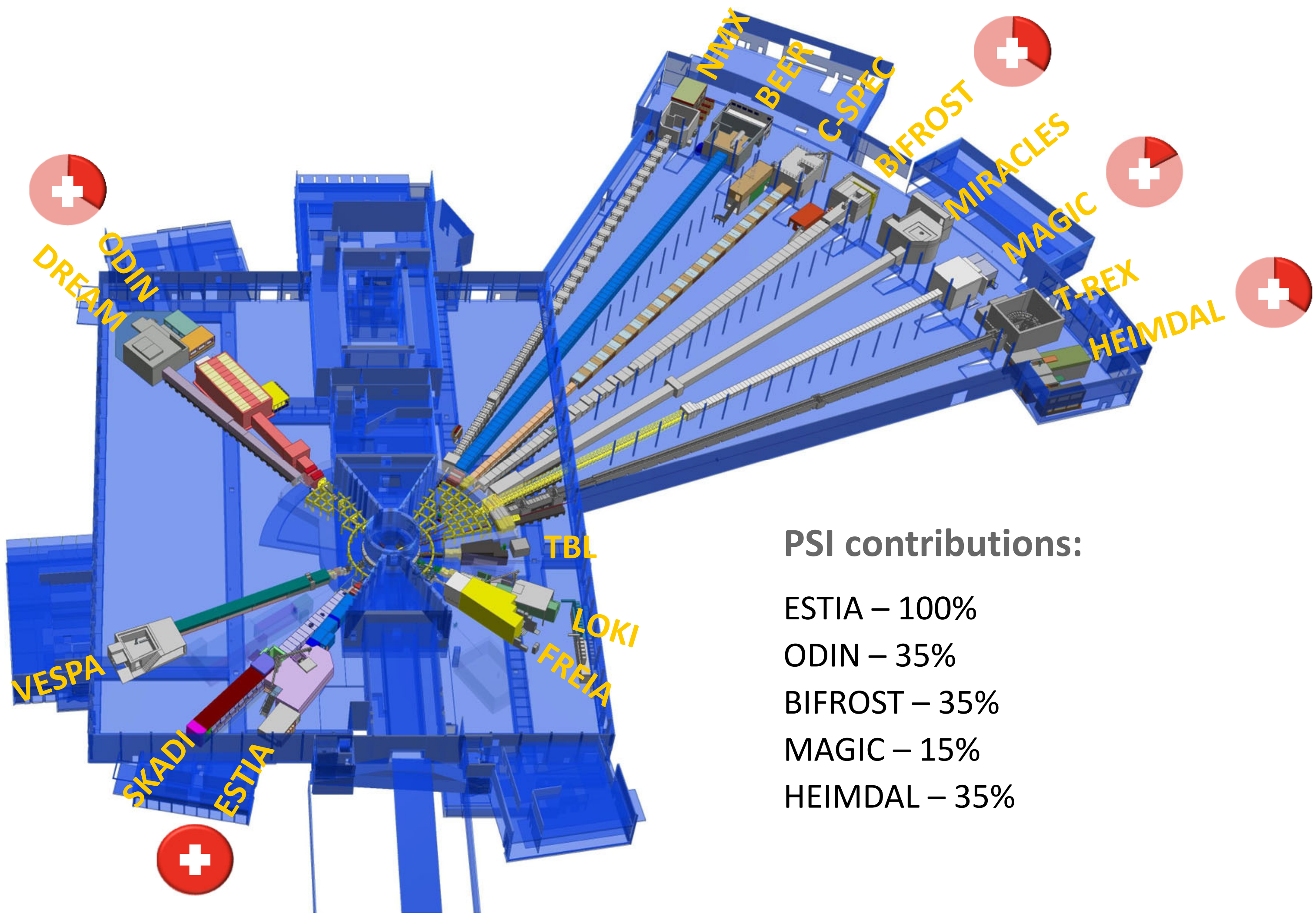
Planning → Construction of Source and Instrument Design → Instrument Buildup → Commissioning → User Operation

2014 **2021** **2023** **2025** **2027**

ESS Neutron Instruments

Swiss contribution:

- Total 165.6 MCHF (~3.5% until 2026)
- In-kind instruments fully provided by PSI (34 MCHF)



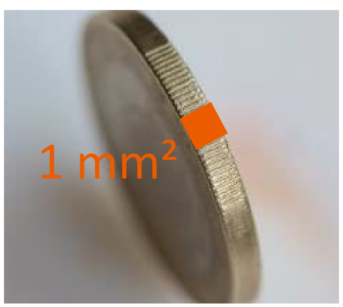
PSI contributions:

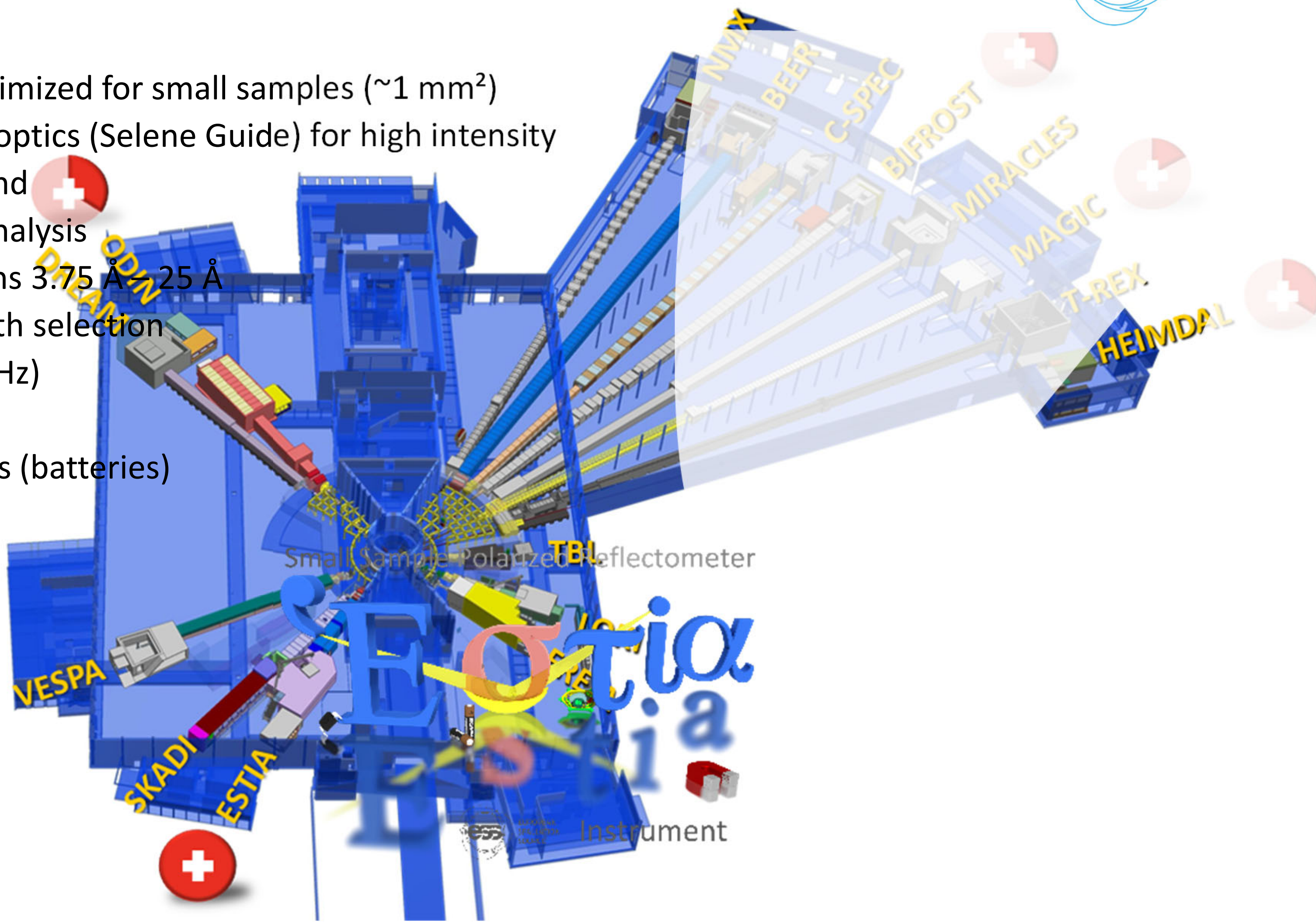
ESTIA – 100%
ODIN – 35%
BIFROST – 35%
MAGIC – 15%
HEIMDAL – 35%

Instrument Estia

- Reflectometer optimized for small samples (~1 mm^2)
- Focusing neutron optics (Selene Guide) for high intensity and low background
- Full polarization analysis
- Usable wavelengths 3.75 Å – 25 Å
- Versatile bandwidth selection (14 Hz, 7 Hz, 4.66 Hz)

→ diffusion processes (batteries)
→ magnetic particles
→ heterostructures

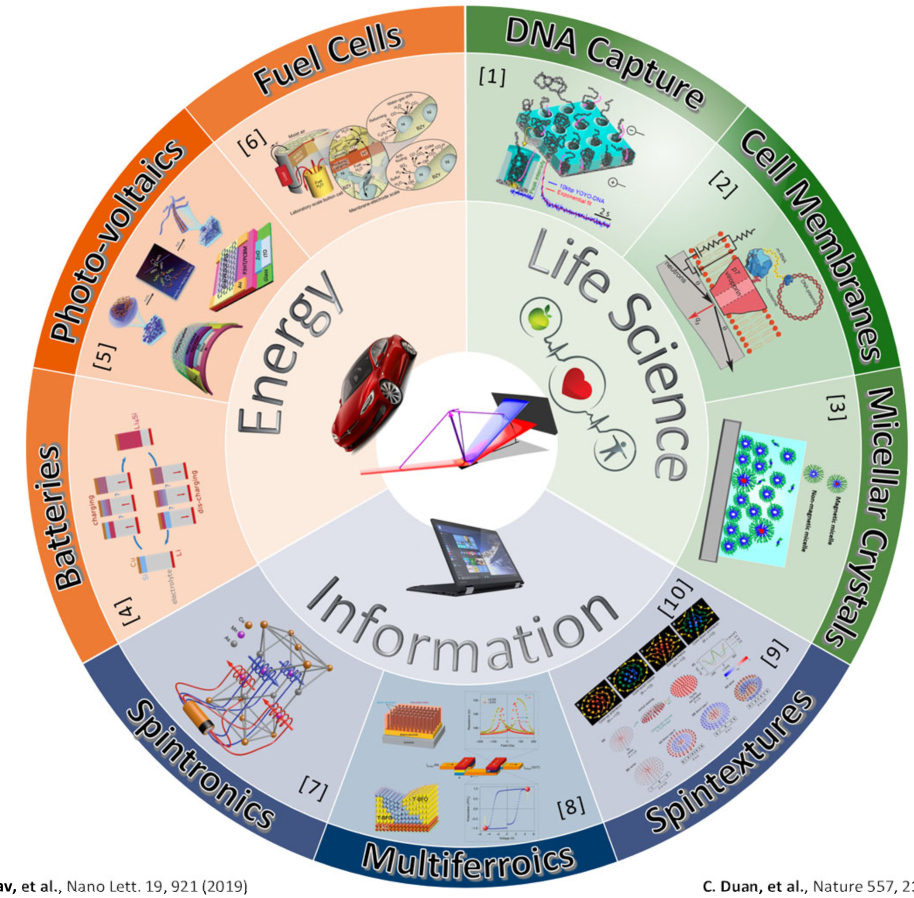




PAUL SCHERRER INSTITUT PSI

Estia Science Case

- Focusing reflectometry
  - tiny samples down to 1 mm²
- Full polarization analysis
- High intensity for sub-s measurement on standard size
- Sample environment
  - low-T
  - high magnetic fields
  - solid-liquid interfaces
- Horizontal scattering geometry
  - extended sample space
  - convenient access
  - q up to 2 $Å^{-1}$



[1] **V. Jadhav, et al.**, Nano Lett. 19, 921 (2019)
[2] **T. Soranzo, et al.**, Scientific Reports 7, 3399 (2017)
[3] **A. Saini, et al.**, Langmuir 35, 3980 (2019)
[4] **D. Uxa, et al.**, J. Phys. Chem. C 123, 22027 (2019)
[5] **Y. Li, et al.**, Adv. Energy Mat. 8, 1701791 (2017)
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T. Jungwirth, et al., Nature Phys. 14, 200 (2018) [7]
N. A. Spaldin & R. Ramesh, Nature Mat. 18, 203 (2019) [8]
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X. Z. Yu, et al., Nature 564, 95 (2018) [10]

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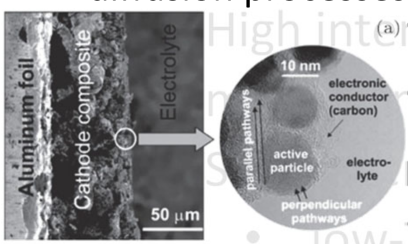
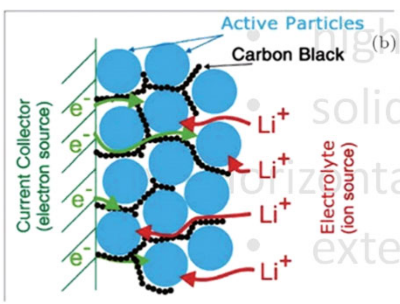
Estia Science Case

EUROPEAN SPALLATION SOURCE

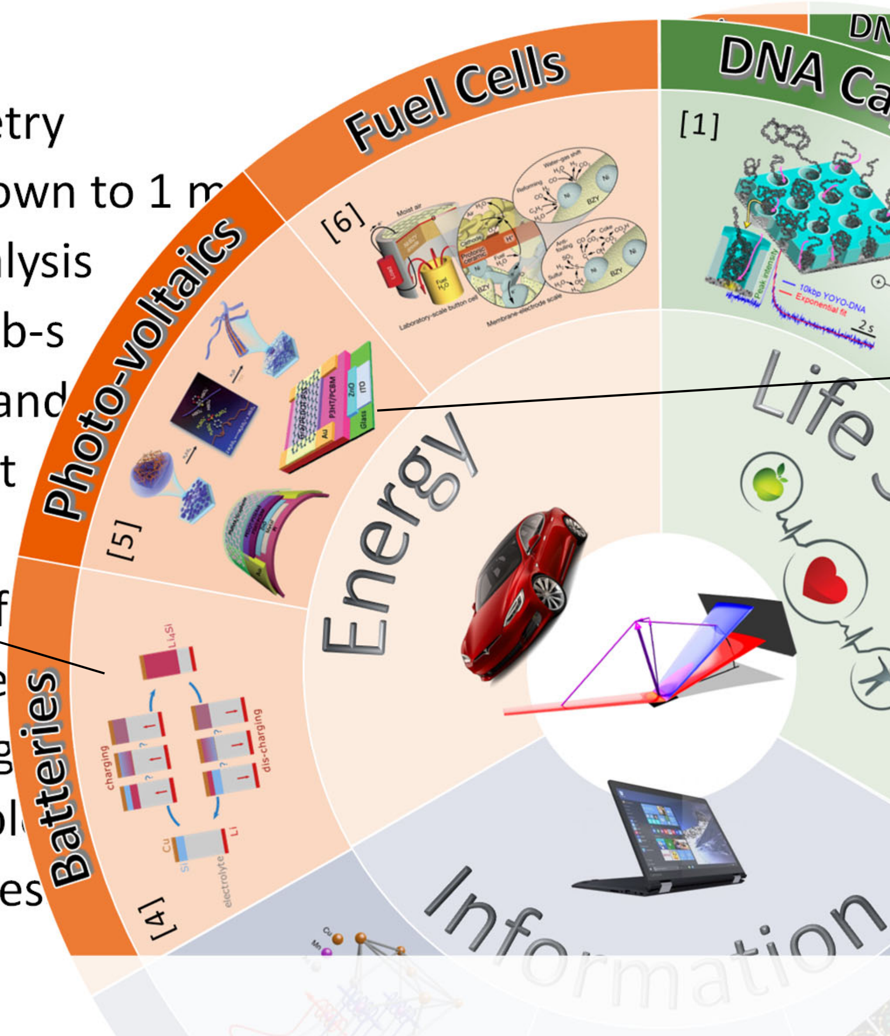
- Focusing reflectometry
  - tiny samples down to 1 m
- Full polarization analysis
- High intensity for sub-s
- ment on stand
- environment
  - low-T
  - high magnetic f
  - solid-liquid inte
- Horizontal scattering
  - extended sampl
  - convenient acces
  - q up to 2 Å-1

diffusion processes

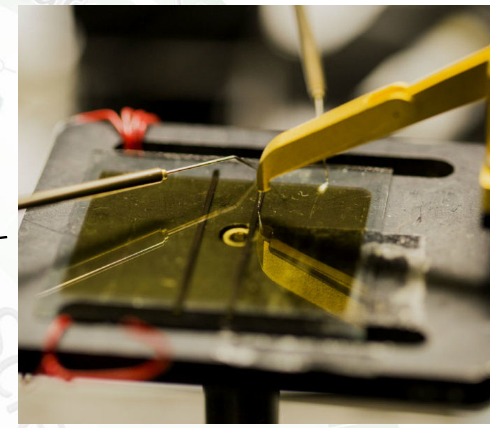


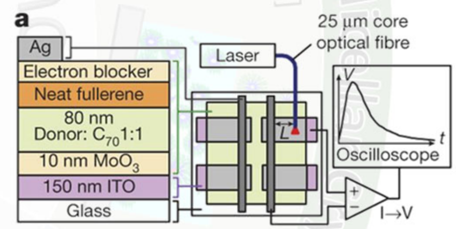


Gao Jian, et al., Chinese Physics B 25, 018210 (2016)



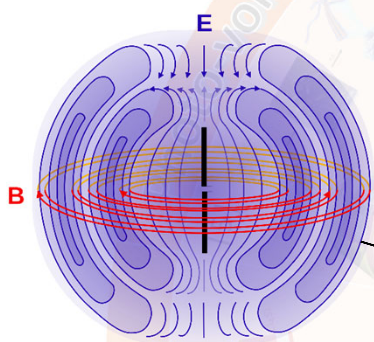
selective device areas



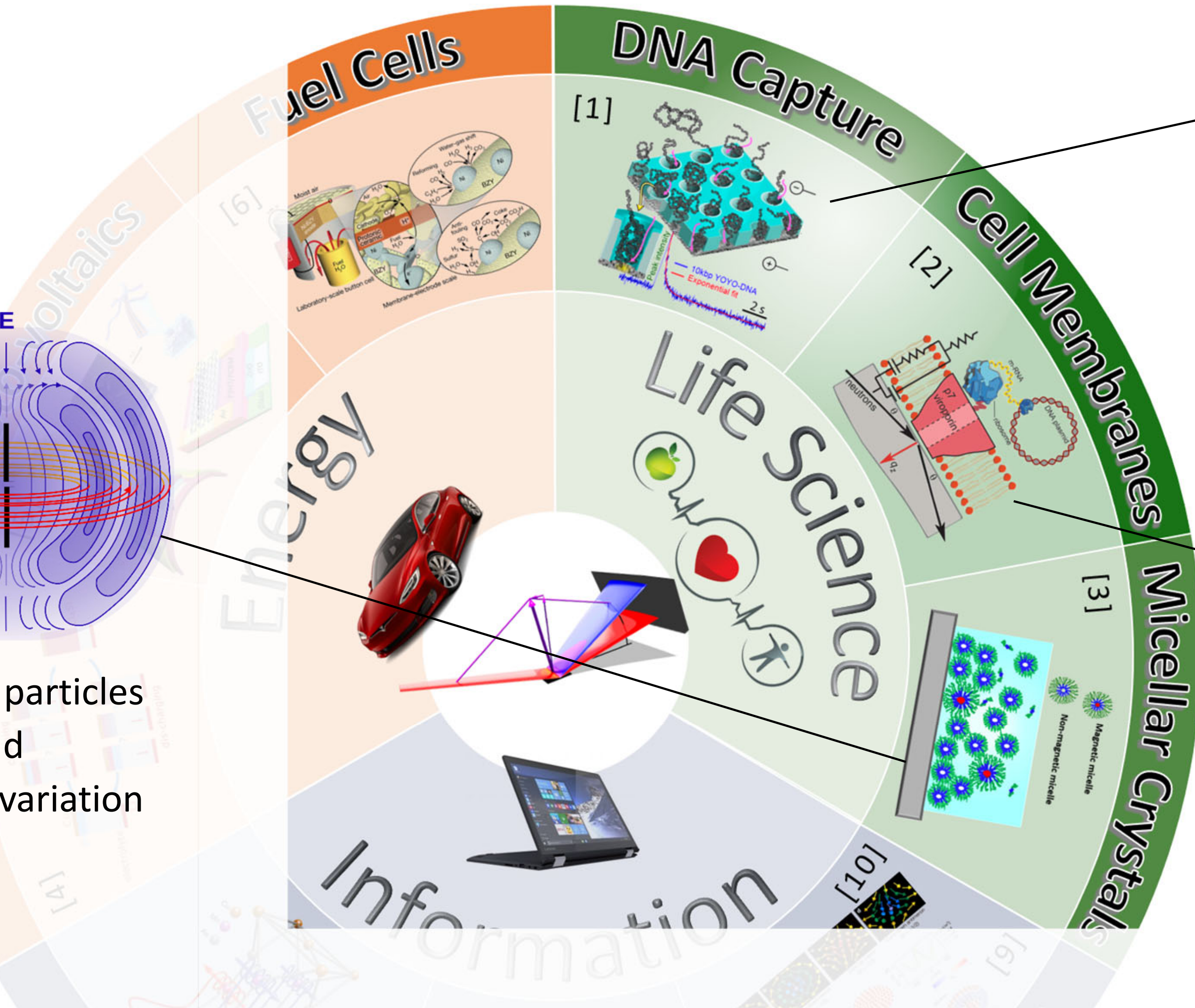


Quinn Burlingame, et al., Nature 554, 77 (2018)

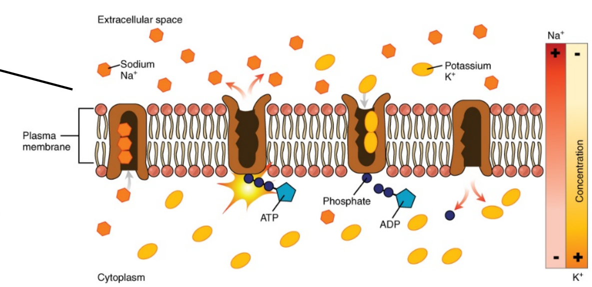
Estia Science Case



magnetic particles
and
-contrast variation



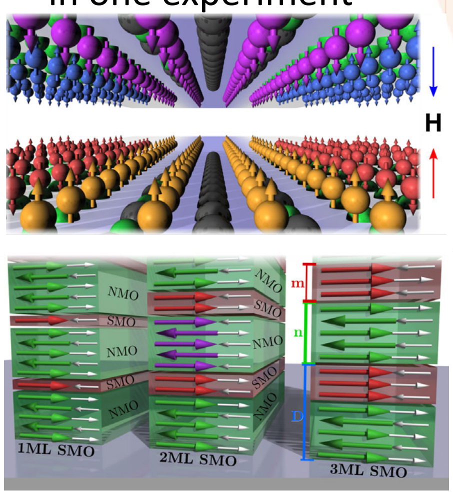
small amounts



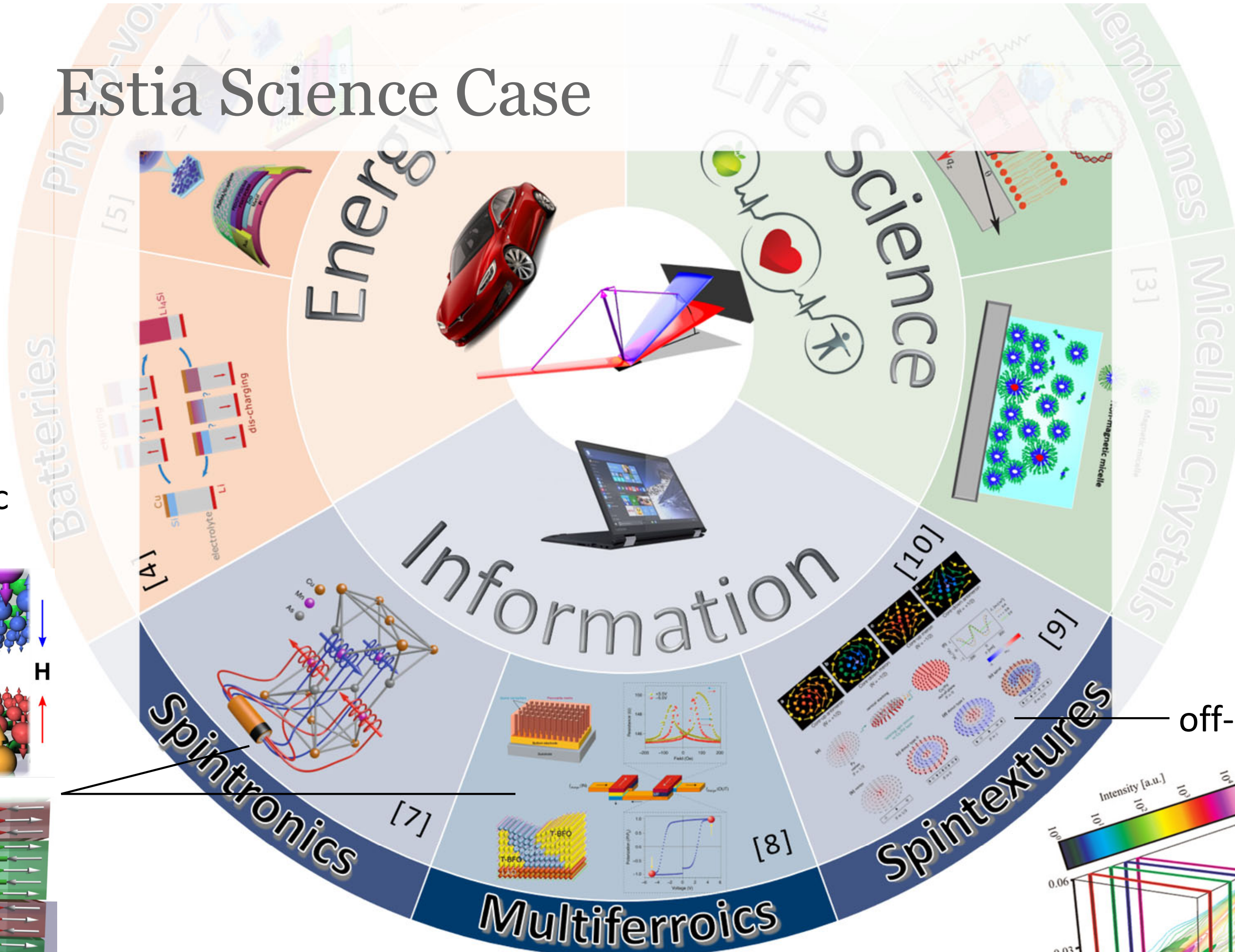
in-situ dynamics

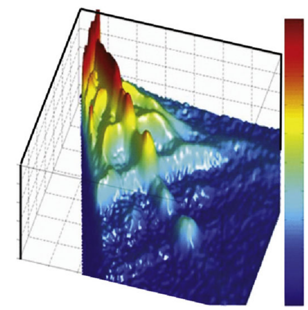
Estia Science Case

anti- and ferromagnetic
in one experiment

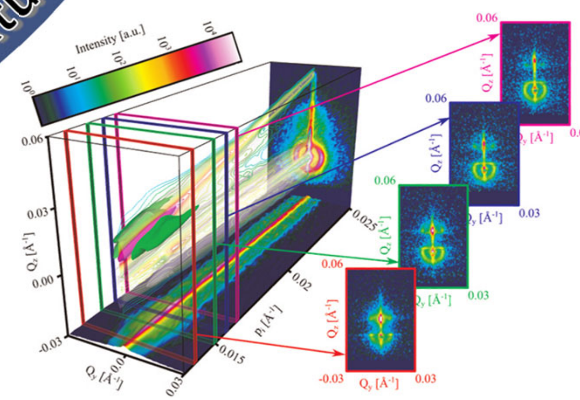


Artur Glavic, et al., Phys. Rev. B 93, 14 (2016)



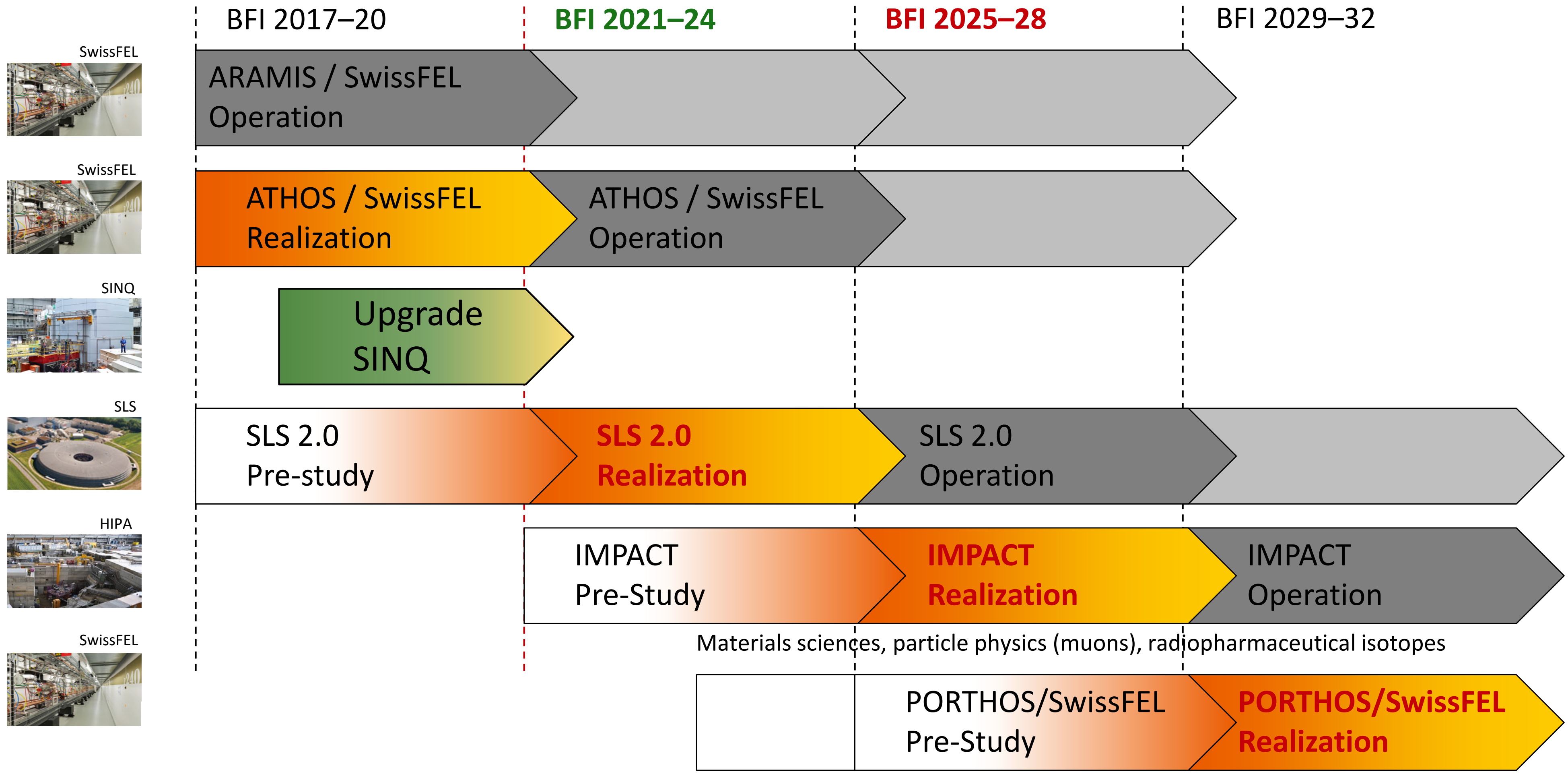


off-specular and GISANS

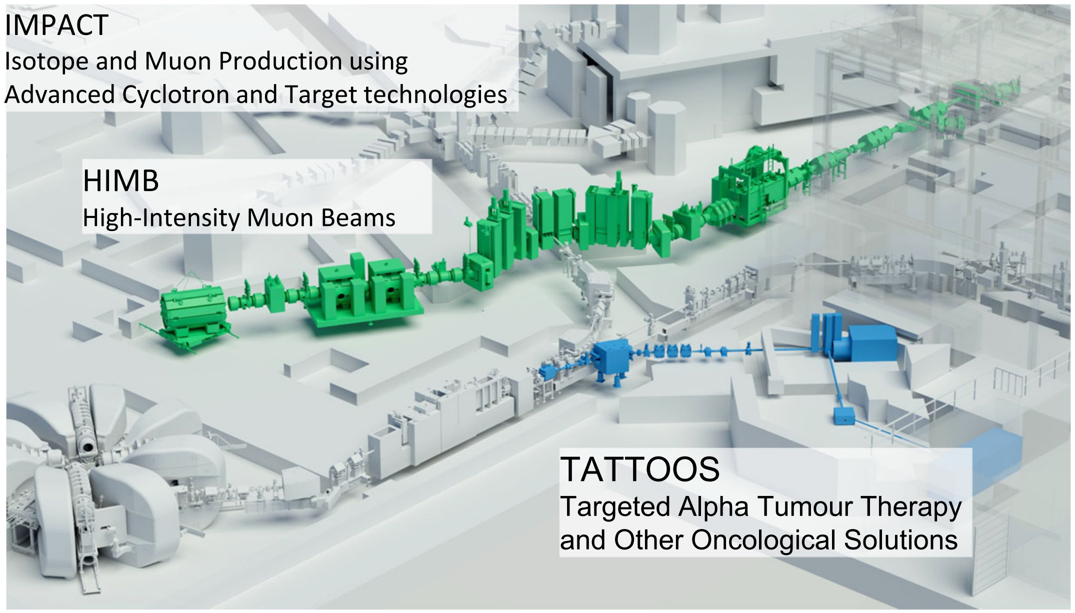


V. Lauter, et al., Ref. Mod. Mat. Sci. Eng., Elsevier (2016)

Research Infrastructure Projects at PSI

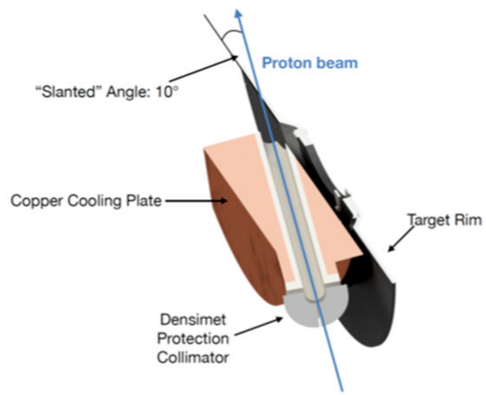


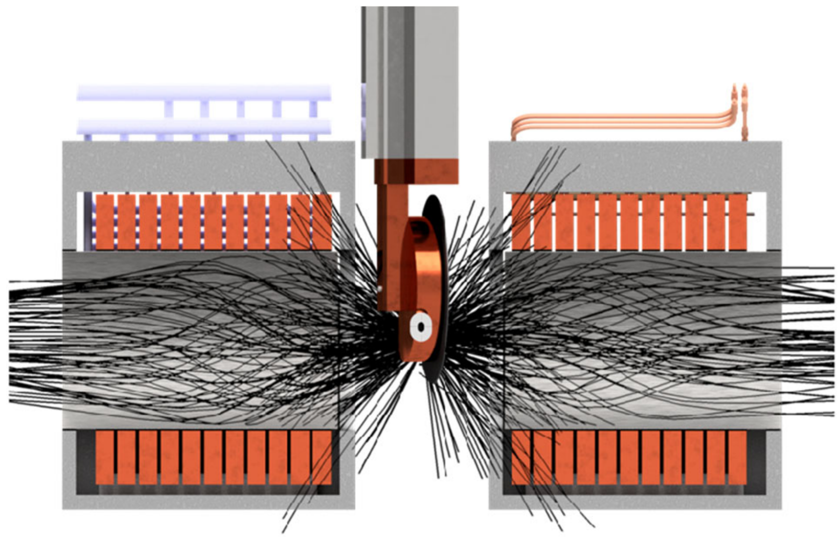
IMPACT: HIMB + TATTOOS



- Complete rebuild of existing target station and beamlines for 100x improved muon intensities reaching 10^{10} μ^{+}/s.
- Research topics:
  - Searches for rare muon decays
  - Improved materials science with muons: faster, smaller/multiple samples, higher pressure
  - High-brightness muon beams
  - Research with high-rate, low-energy negative muon beams
  - …

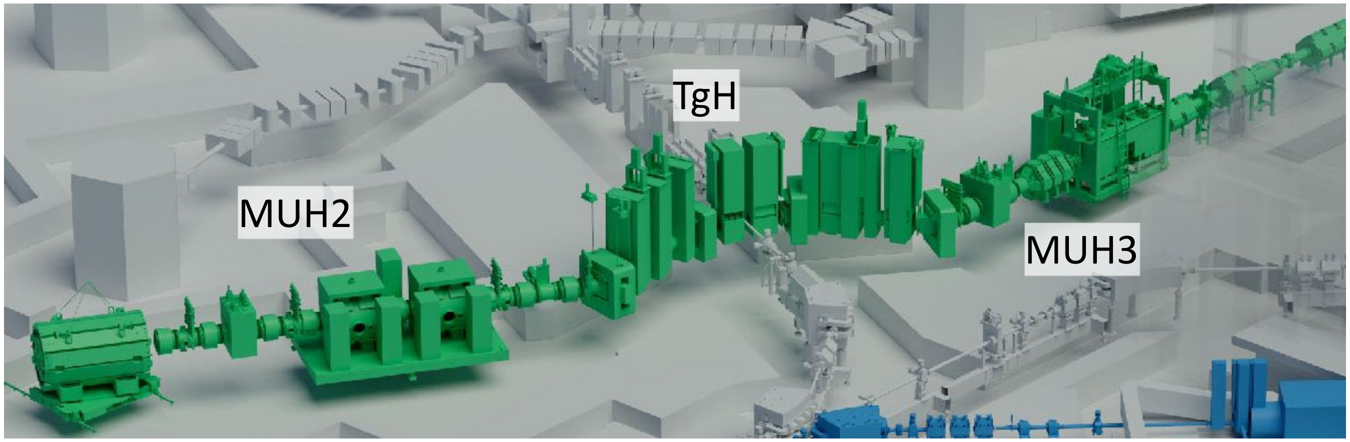
Split Capture Solenoids for Muon Collection





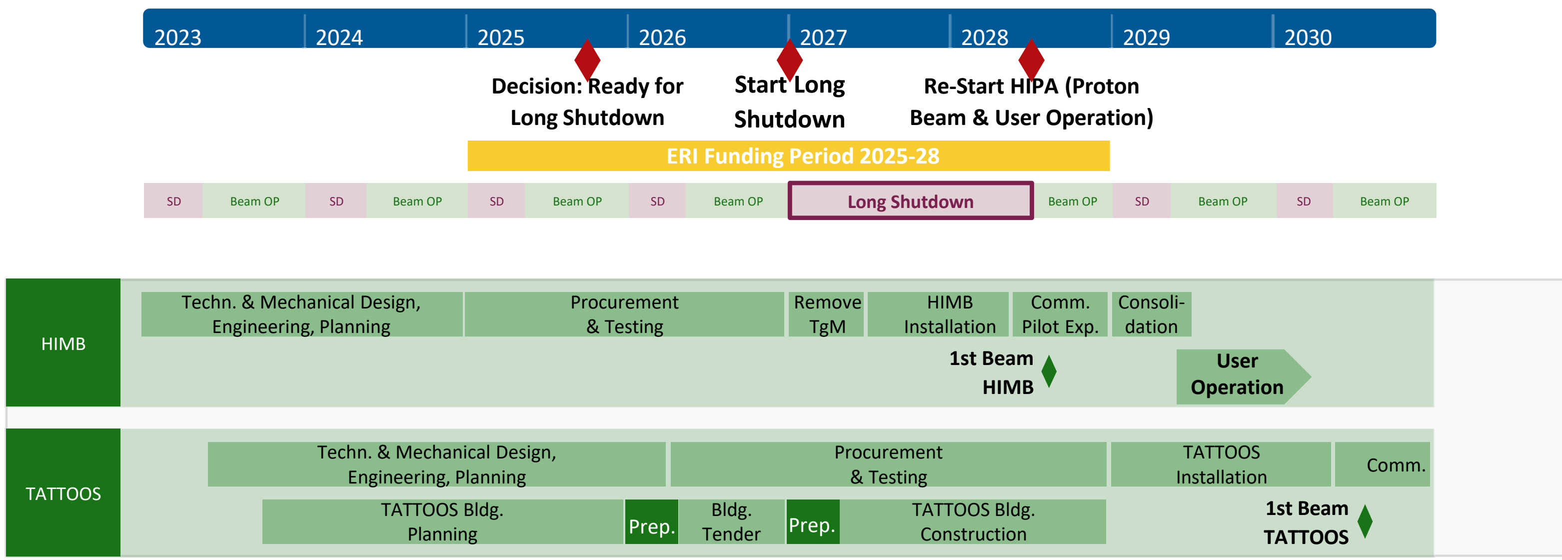
- Two normal-conducting, radiation-hard solenoids 250 mm away from target to capture surface muons
- Central field of solenoids up to 0.45 T
- Graded-field capture solenoid for improved muon collection: stronger field at capture side, weaker at exit

MUH2/MUH3 Beamlines



- Layout of target and beamlines:
  - New TgH at the same location as current TgM
  - 90 degree angle of muon beamlines with first bend in the upstream direction
- MUH2 for particle physics using high-transmission solenoid based beamline
- MUH3 for μSR solenoid based beamline until experimental area; couples into existing beamline

Timeline


2023
2024
2025
2026
2027
2028
2029
2030
Decision: Ready for Long Shutdown
Start Long Shutdown
Re-Start HIPA (Proton Beam & User Operation)
ERI Funding Period 2025-28
SD
Beam OP
Long Shutdown
HIMB
Techn. & Mechanical Design, Engineering, Planning
Procurement & Testing
Remove TgM
HIMB Installation
Comm. Pilot Exp.
Consoli-dation
1st Beam HIMB
User Operation
TATTOOS
Techn. & Mechanical Design, Engineering, Planning
Procurement & Testing
TATTOOS Installation
Comm.
TATTOOS Bldg. Planning
Prep.
Bldg. Tender
Prep.
TATTOOS Bldg. Construction
1st Beam TATTOOS

Thank you !

Thanks to:

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Artur Glavic
Stefan Janssen
Michel Kenzelmann
Klaus Kirch
Andreas Knecht
Bernhard Lauss
Hubertus Luetkens
Thomas Prokscha
Zaher Salman

PAUL SCHERRER INSTITUT PSI

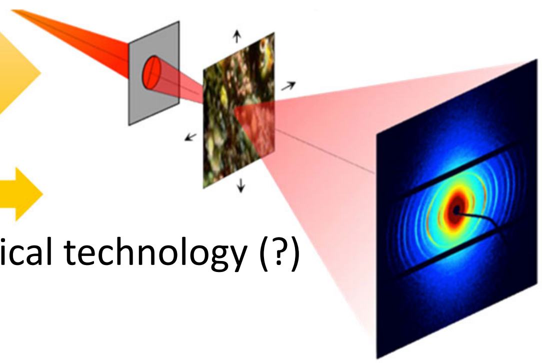
Spin-off: products out of fundamental research

15 years

R&D: pixel detector for particle physics

CMS detector at CERN, Geneva

spin-off



medical technology (?)

PILATUS 6M Pixel Detector
(Dectris Ltd., Switzerland)

Synchrotrons, world-wide

Applications in materials research as state-of-the-art X-ray detector