PAUL SCHERRER INSTITUT

PSI

CHART

Swiss Accelerator Research and Technology

Stéphane Sanfilippo on behalf of the Magnet Section & MagDev Team :: Paul Scherrer Institut

Research and Technological facilities at the Institute Paul Scherrer

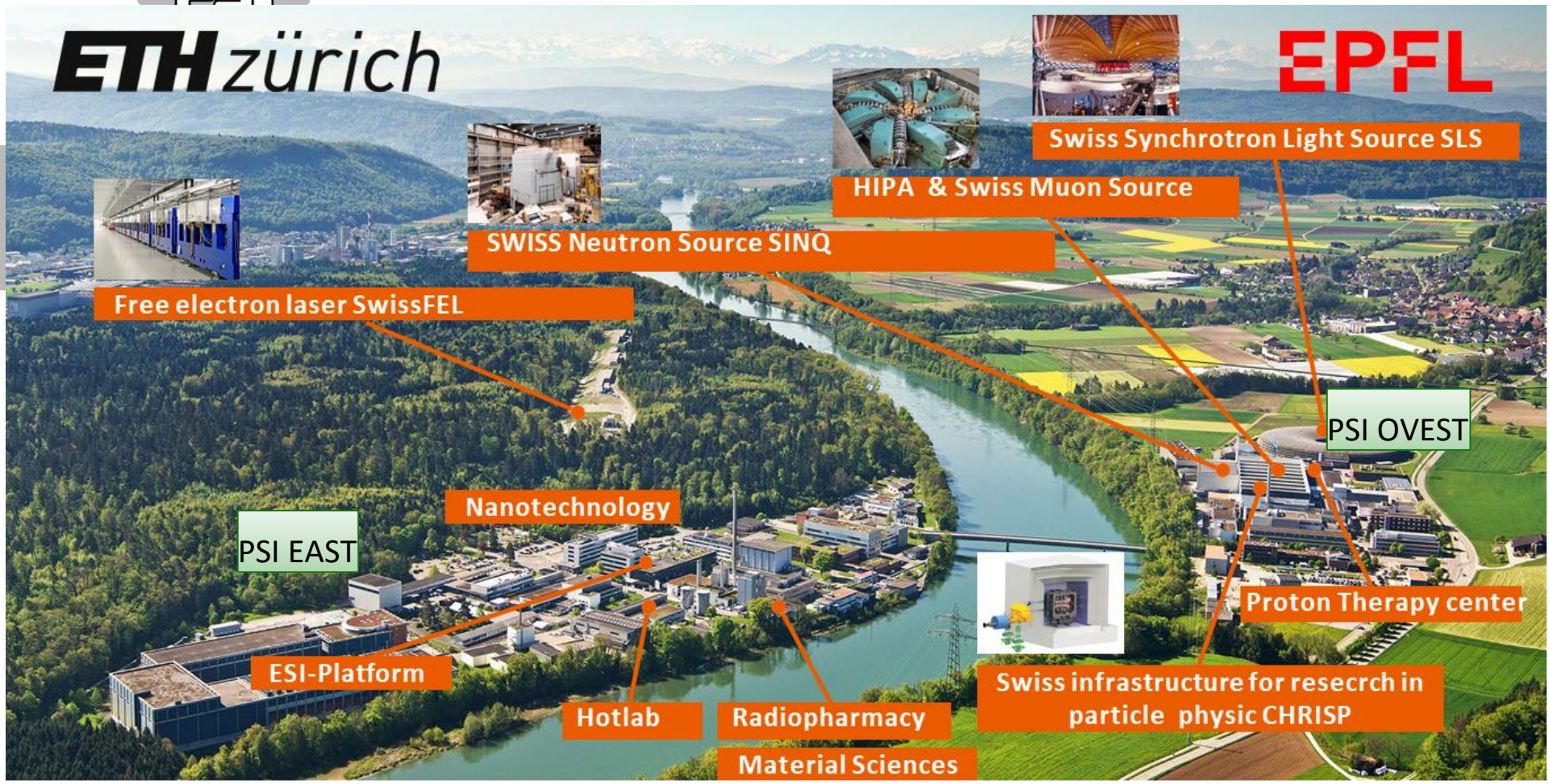
I.Fast - ETIAM – Test Facilities Superconducting Magnets Workshop
INFN-LASA November 2022

Plan

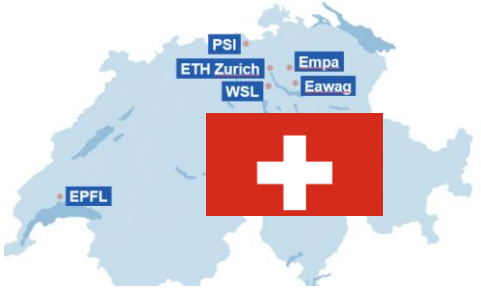
- The PSI context :
  - Innovation park @ PSI
  - The Large Research facilities & Services example with the Swiss Light Source

- Technological facilities for the magnets
  - The project : Competence center for Magnet &IDs
  - Infrastructure development
  - Collaboration with industries

Paul Scherrer Institut in the ETH domain



2100 employees- member of the ETH domain



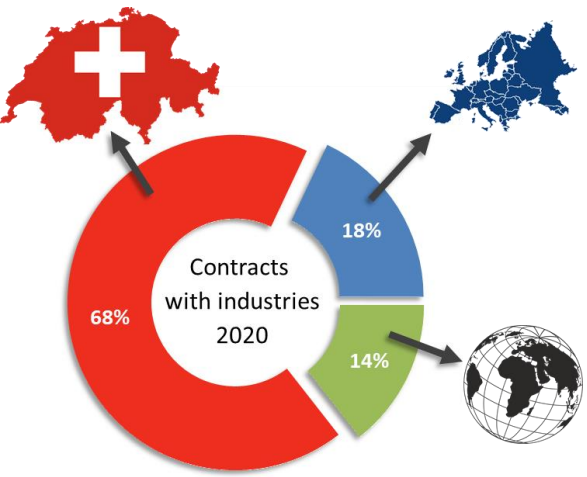
- R&D on : Matter and Materials, Energy, Environment Human Health, Accelerator Technologies & Instruments
- Education and technology transfer

Collaboration with Industries

approx. **300 contracts per year**, of which approx. 50% with industrial partners

Approx. 10% industrial user share in the use of the large-scale research facilities

- Successful collaborations with corporations from various industries
  - Automotive
  - Pharmaceuticals
  - Chemistry, food
  - Electronics
  - Energy
  - Aerospace…



Courtesy John Millard

Partnership with Industries

- **Service**
- **Contract research**
- **Research cooperation**

- **Key topics**
  - Funding
  - IP rights
  - Publication rights (PSI)
  - Strategic interest on the part of PSI

Courtesy John Millard

PARK innovAARE – the innovation park at Paul Scherrer Institute

35,000 m^2 including laboratories

20 members

Promote technology and know-how transfer (science to business), synergies and interdisciplinary collaborations in

- particle acceleration technology,
- matter and materials,
- human health
- energy and the environment

A set of companies and one technology transfer center offer specialized services

SLS Techno Trans AG

Excelsus Structural Solutions

EXPOSE DATA COLLECTION SERVICE

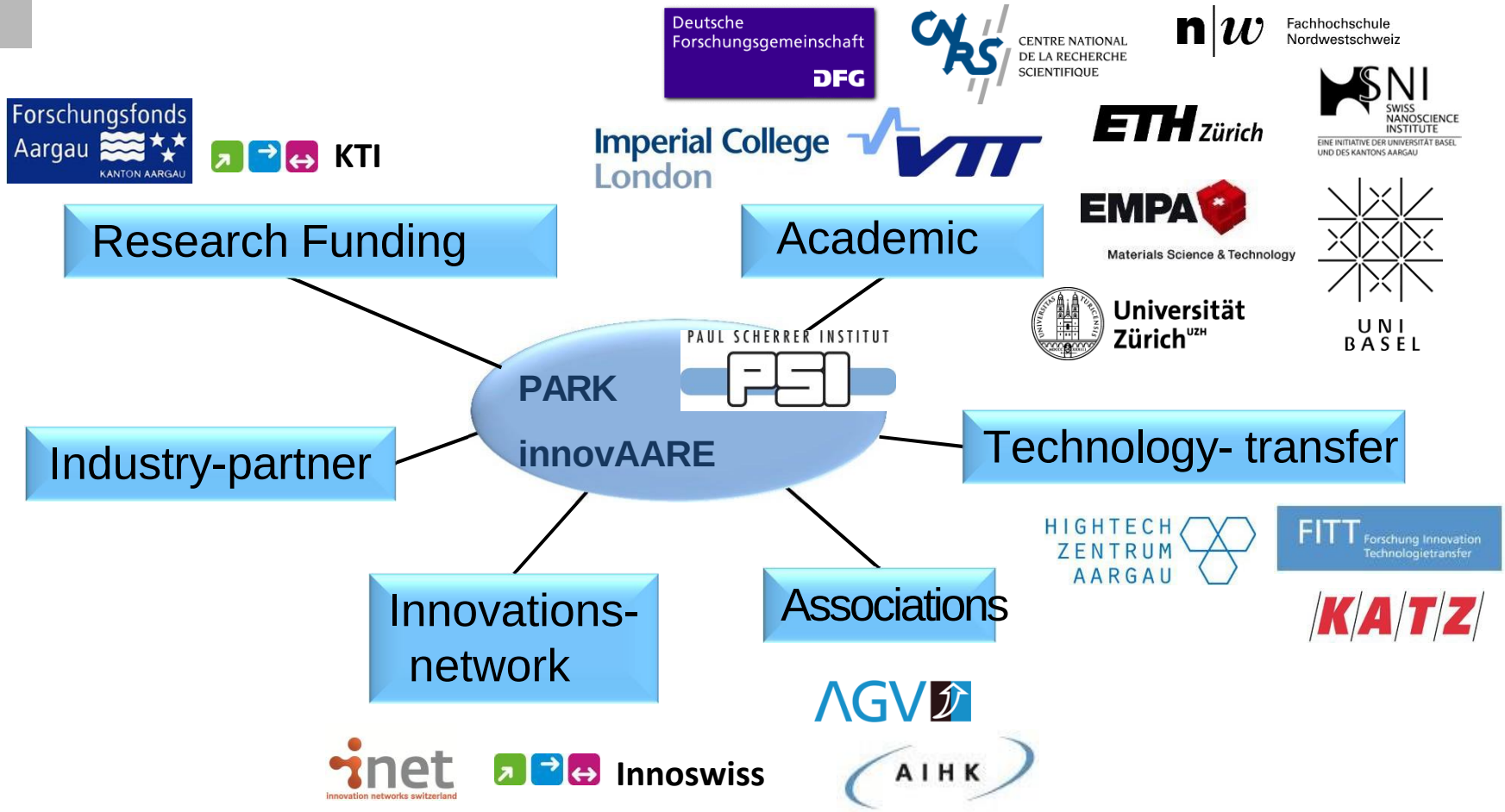
eadpro

anaxam analytics for advanced manufacturing

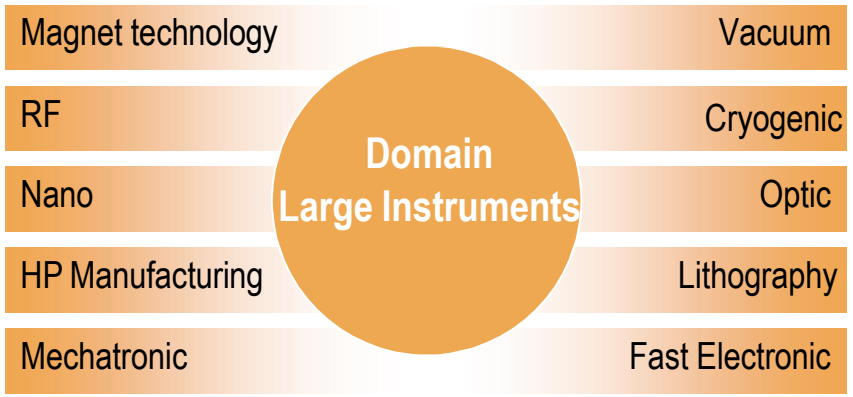
ACCELERATOR TECHNOLOGY

High school and innovation network

The university and innovation support network acts as a motor



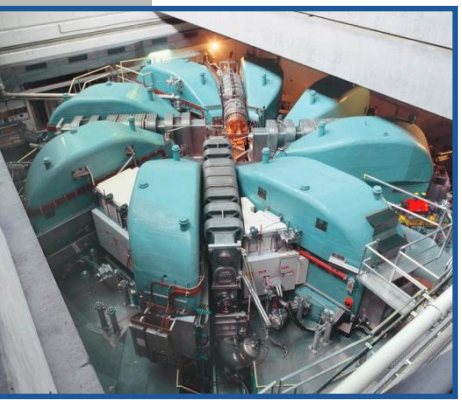
Technologie domains of innovAARE



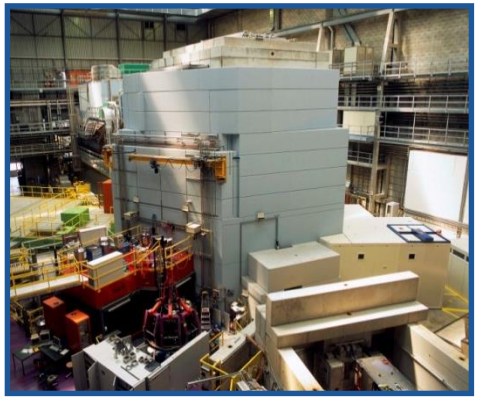
Large Research facilities & CPT at PSI

High Intensity Proton Accelerator Complex

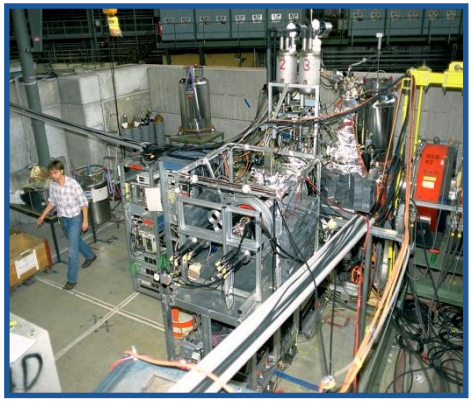
Proton Accelerator



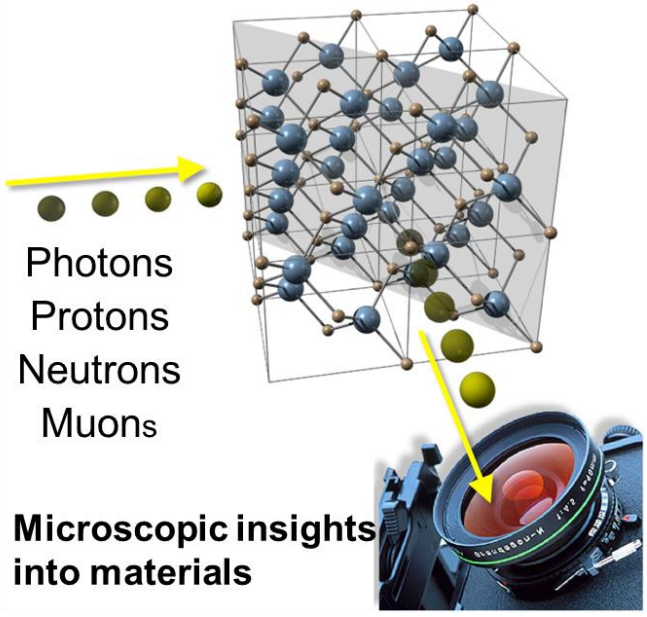
Spallation Neutron Source (SINQ)



Swiss Muon Source (SμS)



Swiss Light Source (SLS)



Microscopic insights into materials

Protons beam therapy

Swiss Free Electron Laser (SwissFEL)

Muon Instruments at PSI : SμS (Swiss Muon Source)

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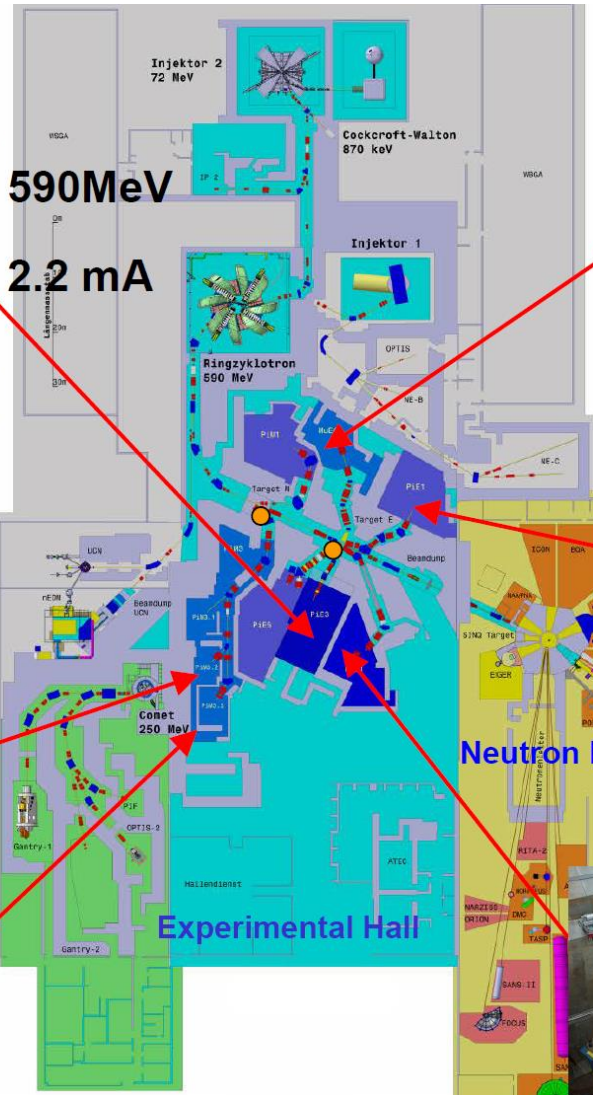
HAL-9500

High Field and Low Temperature

9.5 T

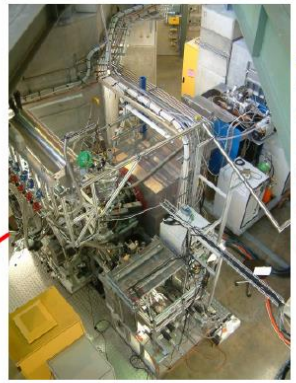
< 20 mK



LEM

Low-energy muon beam and instrument , tunable energy (**0.5-30 keV**, μ^+), *thin-film, near-surface and multi-layer studies*

(1-300 nm)



0.3 T

2.5 K

DOLLY

General Purpose Surface Muon Instrumen

μ^+ energy: **4.2 MeV**

0.5 T

250 mK

GPS

General Purpose Surface Muon Instrument

Muon energy: **4.2 MeV** (μ^+)

0.6 T, 1.6 K

Shared Beam Surface Muon Facility (Muon On REquest)

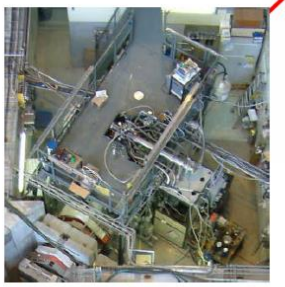
LTF

Low Temperature Facility

Muon energy: **4.2 MeV** (μ^+)

3 T,

20 mK- 4 K



GPD

General Purpose Decay Channel Instrument

Pressure studies

Muon energy: **5 - 60 MeV** (μ^+ or μ^-)

0.5 T,

300 mK

2.8 GPa

6 research instruments

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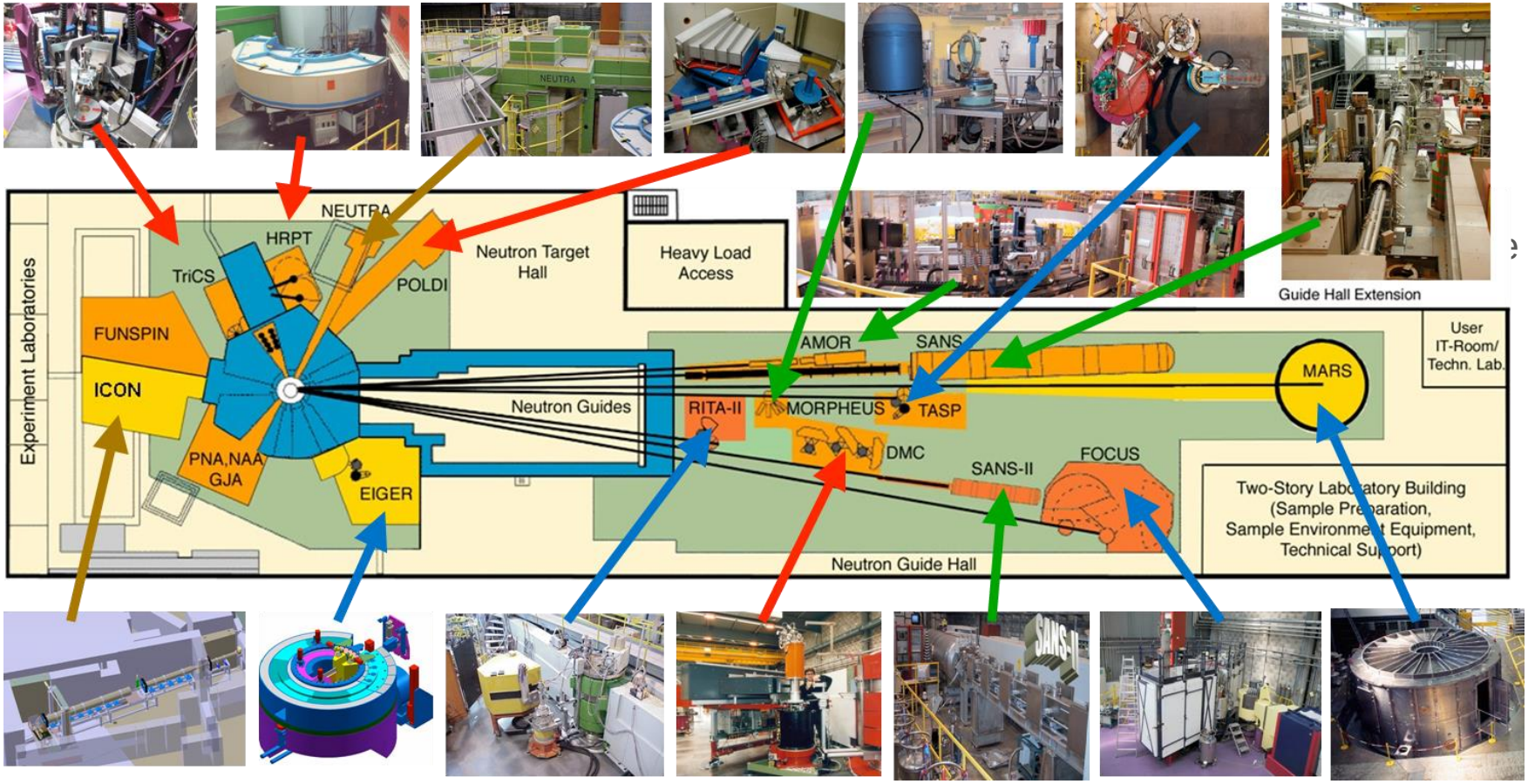
SINQ Experiments

16 experiments

- Diffractometers (ZEBRA, POLDI…,)
- Reflectometers (AMOR, MORPHEUS, MARS….)
- Spectrometers (FOCUS, TASP, RITA II…)
- Small angles scattering (SANS I, II…..)
- Non diffractive and special instruments (NEUTRA,ICON…)



Swiss Synchrotron Light Source

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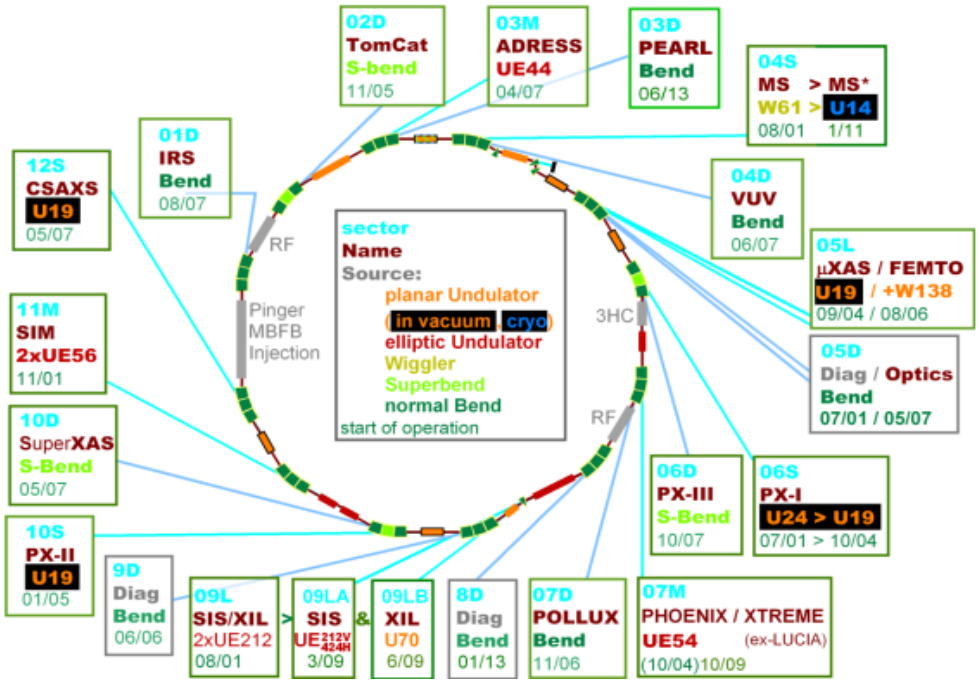
19 beam lines in operation



Spectroscopy

Hard x-ray spectroscopy
Metrology
Optics
Detector Calibrations
Soft x-ray spectroscopy

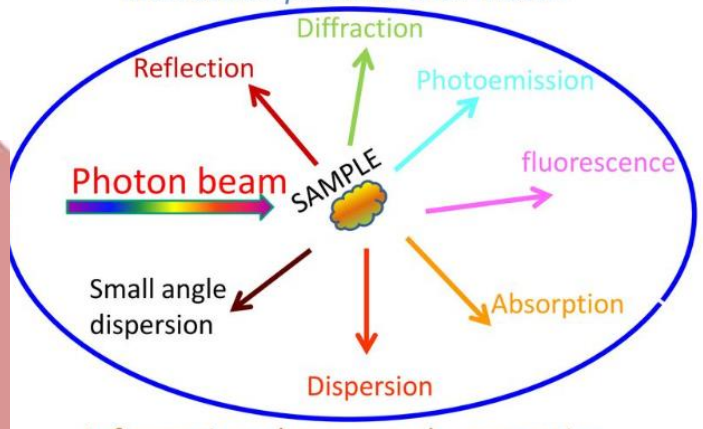
Scattering

Hard x-ray diffraction
Hard x-ray scattering
Macromolecular crystallography
Soft x-ray scattering

Imaging

Hard x-ray imaging
Lithography
Soft x-ray scattering

Interaction photons with matter



Information about sample properties

Industry access to the SLS : 2 ways

1) two beamlines are operated with partners from the protein crystallography area (PX)

PX II

MAX-PLANCK-GESELLSCHAFT

proteros

NOVARTIS

lead pro

Roche

Boehringer Ingelheim

SAI Corporation
Solution and Innovation for data collection

PX III

Boehringer Ingelheim

idorsia

Mitsubishi Tanabe Pharma

Courtesy N. Frijthof

2) Buying beamtime and services via the SLS Techno Trans AG

Beamtime and basic support can be bought via the **SLS Techno Trans AG** (www.synchrotron-analysis.ch).

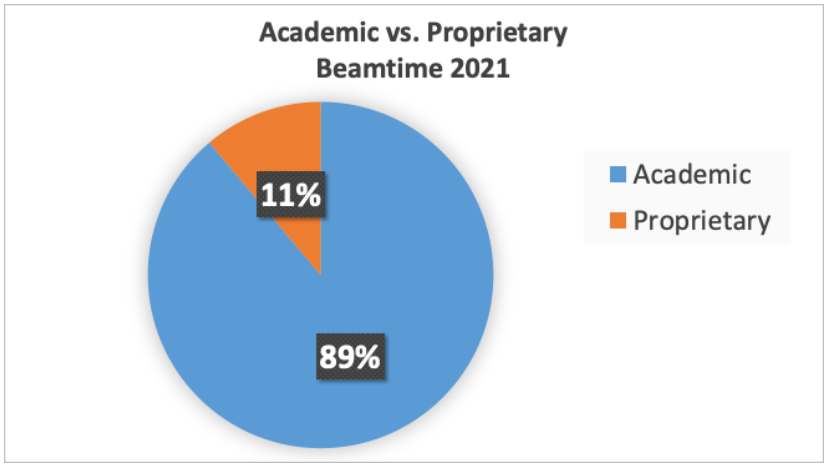
SLS Techno Trans AG

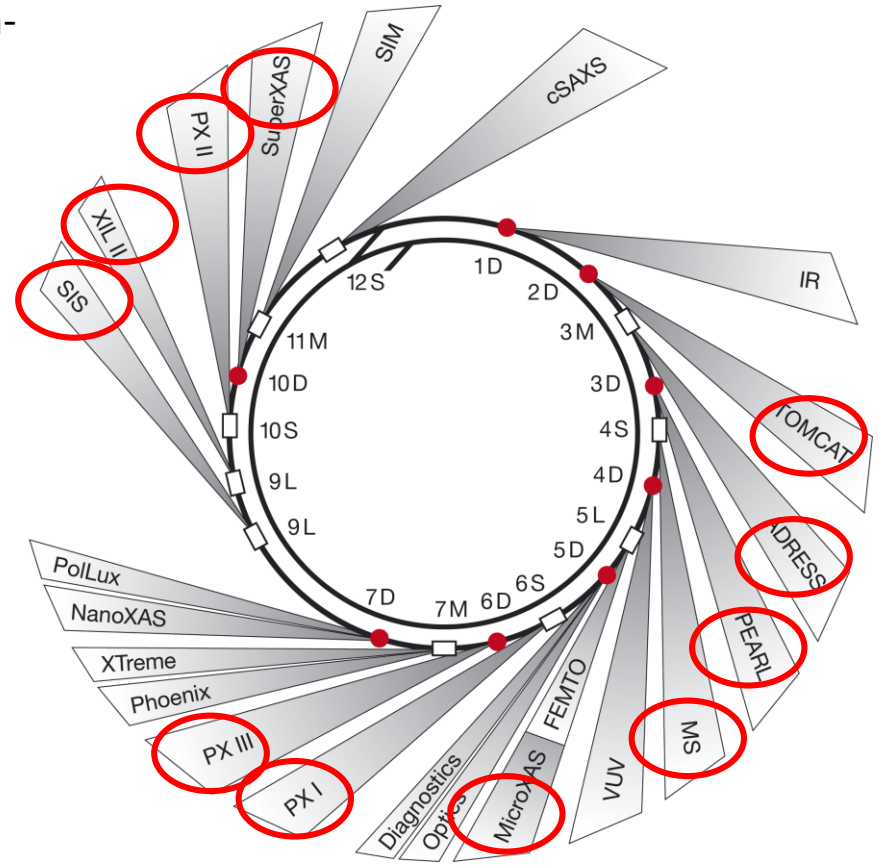
- Measurements at the SLS beamlines
- Use of the clean rooms
- Support & advice by PSI specialists (Vacuum, RF, Magnets….)
- Preparation, execution and analysis of the measurements

Closing the gap

Swiss Light Source – company costumers

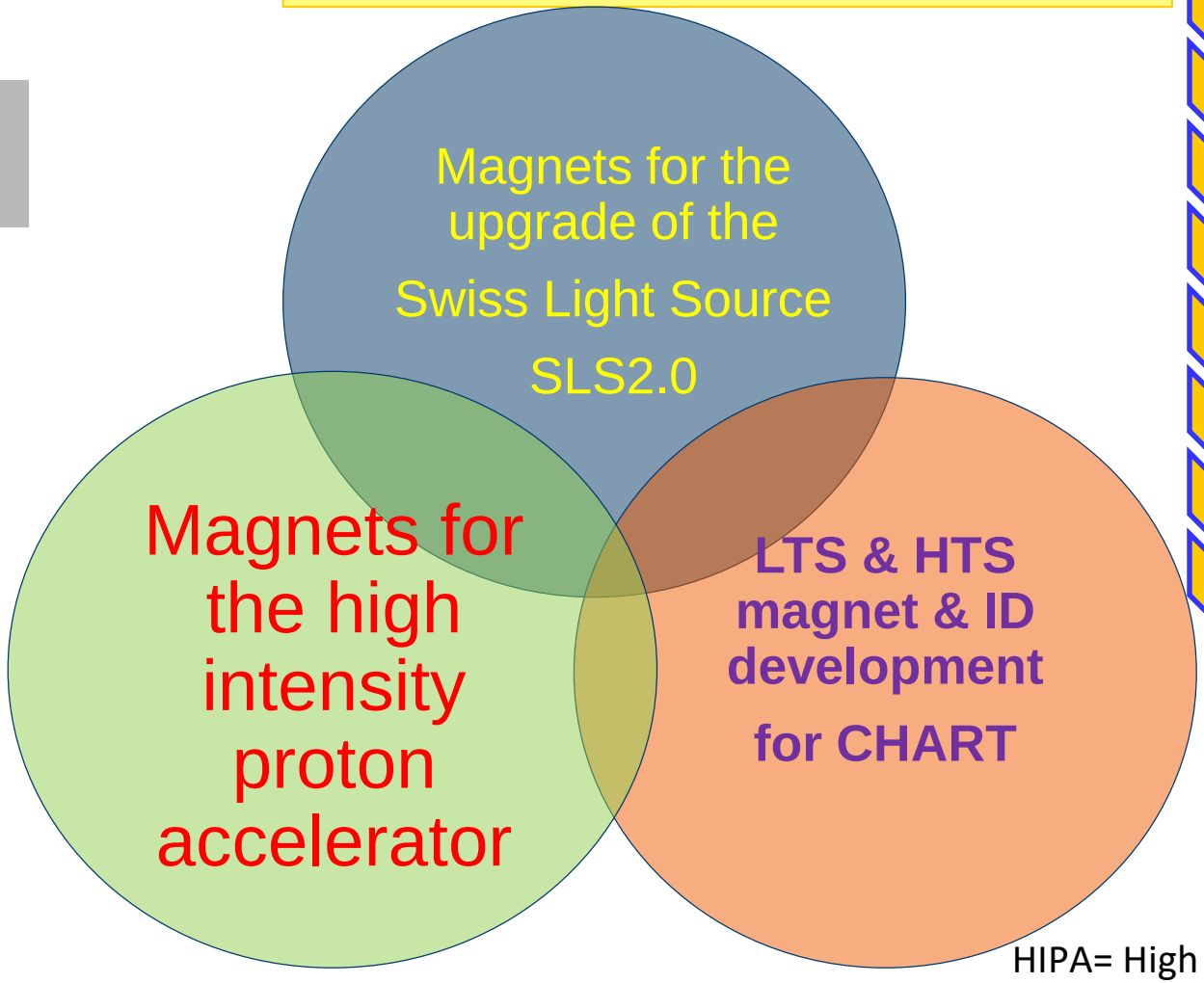
Besides research collaborations, companies have also access to the SLS. Several beamlines are regularly used and keep beam-time available on short term noticed.





Courtesy N. Frijthof

Magnet section
Main activities



- Magnetic design
- CAD design
- Procurement
- Assembly (PM &SC magnets)
- Tests @ 4.2 K and 10 K
- Magnetic measurements
- Maintenance &Repair
- Spare

HIPA= High Intensity Proton Accelerator

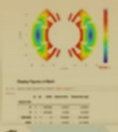
CHART = Swiss Accelerator and Technology

CHART activities at PSI

CHART = "Swiss Accelerator Research and Technology"

- **Swiss research network, consisting of national and international research institutes in Switzerland**





Members : CERN, EPFL, ETHZ, UniGE, PSI (Home Institut)

- **Goal: Support of future accelerators in Switzerland**
  Main task: Future Circular Collider FCC @CERN
  ~50% R&D for superconducting magnets

- **Funding by the participating institutes**
  (CERN ~40% of the total budget)
  Support of the State Secretariat for Education and the ETH Board

CHART goals

Swiss Accelerator Research and Technology

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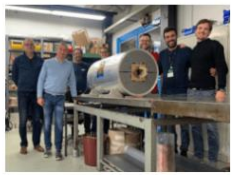
B. Auchmann

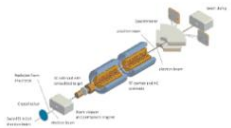
- **Design of superconducting magnets**
- **Coil winding and magnet assembly**
- **R&D in LTS and HTS materials (key technologies)**
- **Development of an infrastructure for LTS and HTS magnet assembly (MagDev Lab) and test**
- **Promote synergies (competences, topics, personnel, equipment) with other projects (HTS Superbends, P3 experiment, superconducting gantry…)**

CHART project at PSI https://chart.ch/psi/



MagDev1

Superconducting Accelerator Magnet R&D



FCCee Injector

Design and positron production test program for FCC-ee Injector

HTS Bulk Undulator

High Temperature Superconducting Undulator for SLS2 Upgrade

- Characterization, interfaces, manufacturing & design techniques
- LTS (CCT, Box Programs, cosine theta subscales…)
- HTS development (coils, magnets….)
- …….

Competence center : Magnets & Insertion Devices

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Know-how

SC magnets

PM and electro magnets

HTS & LTS coils and magnets

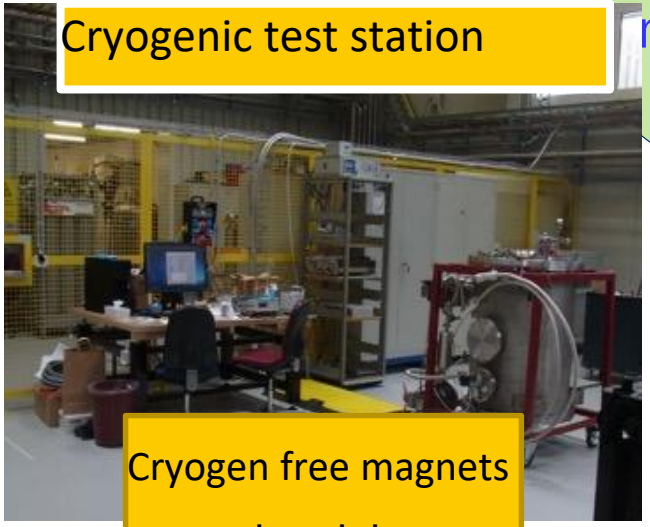
Insertion Devices

Infrastructure

Common workshop, production tools
Winding machines
Impregnation oven
Measurement systems

Measurement hutch

Cryogenic test station



Cryogen free magnets and undulator

Resource

PM based undulator magnetic test

Workshop

1100 m^2 for Insertion Devices & Magnets

Team Organigram

Magnet Section & CHART Magdev Team & Insertion Device group

S. Sanfilippo

MagDev

Superconducting Magnets

Design and analysis

- C. Calzolaio 
- G. Montenero 
- V. Vrankovic 
- R. Riccioli (Post Doc) 

MagDev Team

- C. Zoller 
- M. Duda 
- S. Hellmann 
- M. Daly* 
- D. Sotnikov* 
- J. Kosse* 
- A. Brem* 
- D. Araujo* 
- H. Garcia* 
- Th. Michlmayr* 
- O. Kirby* 

+ 2 technicians in 2023

Engineering and measurements

- A. Gabard 
- R. Deckardt 
- R. Felder 
- P. Berger 
- S. Müller 
- S. Sidorov 
- Y. Studer (from 12/22)

- T. Schmidt 
- M. Calvi 
- M. Brügger 
- S. Denner 
- L. Huber 
- X. Liang (Ph.D) 
- M. Schmidt
- K. Zhang 

* CHART financing

Synergies between the Magnet Section, the Magdev Team and the Insertion Device Group

In house know-how

Swiss Accelerator Research and Technology

Design
- Multiphysics modelling
- Magnetic;
- Mechanics;
- Thermal;
- CAD

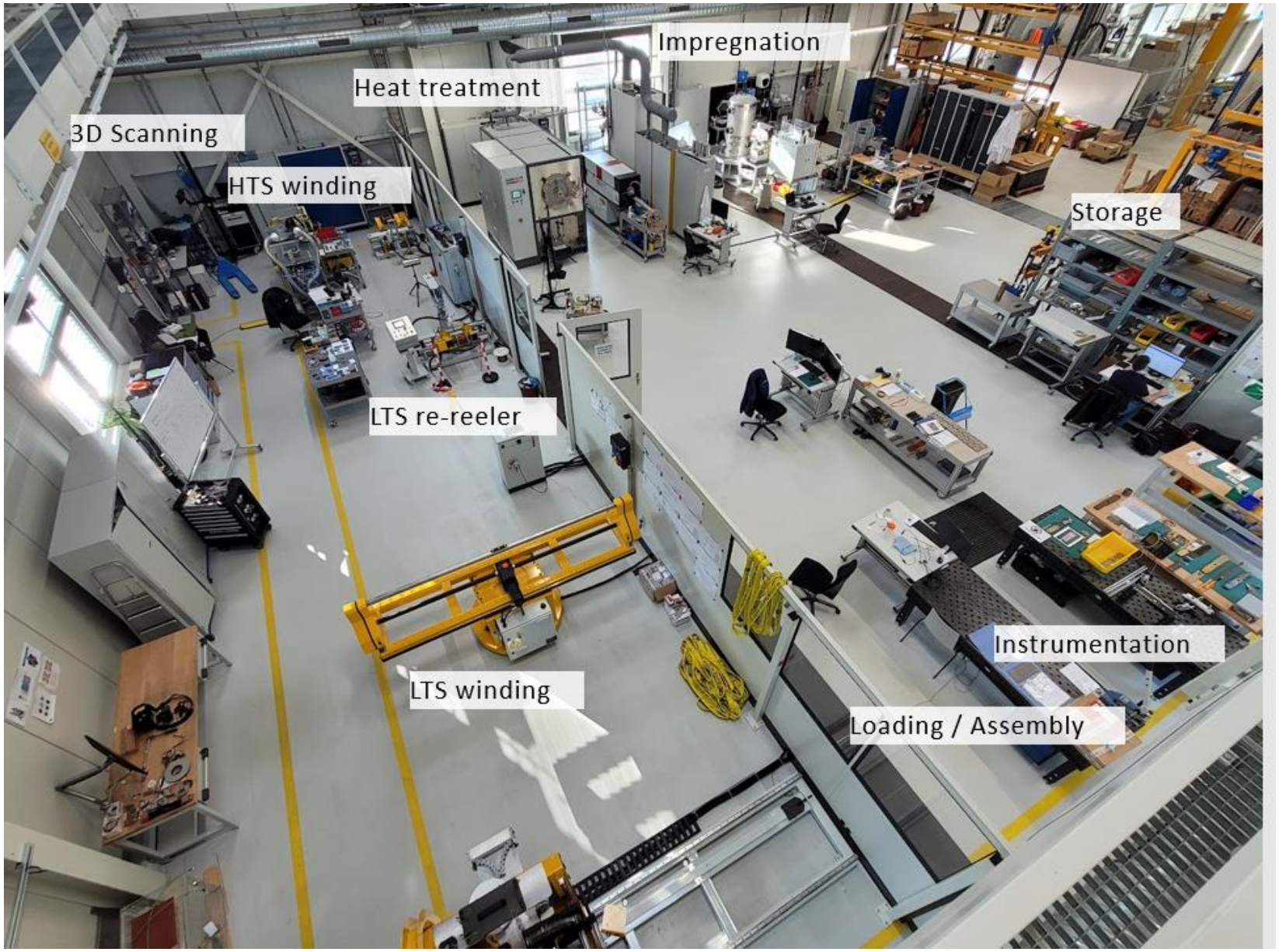
Construction
- Coil winding (LTS, HTS, Cu)
- Heat treatment
- Impregnation technology
- Assembly
- Metrology (LT, Arms, …)

Measurement techniques
- Power tests (in preparation)
- Field strength
- Field mapping
- Multipoles
- Magnetic axis
- Magnetisation PM magnets

In one lab we focus on:

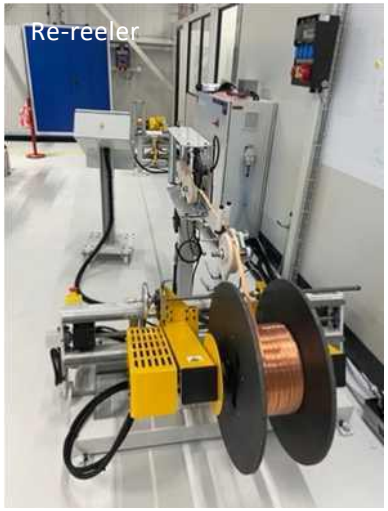
- Room Temperature magnets
  - Resistive;
  - Permanent;
- Superconducting magnets
  - Low Tc superconductors
  - High Tc superconductors
- Insertion devices
  - Permanent magnets
  - High Tc (bulk) superconductors

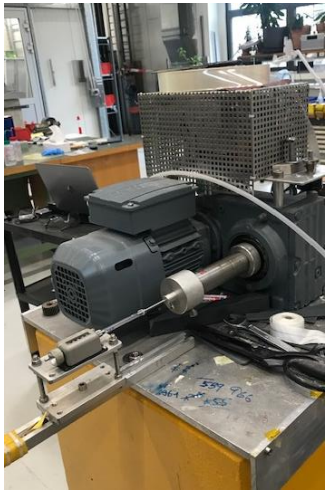
MagDev Laboratory
(applied superconductivity)



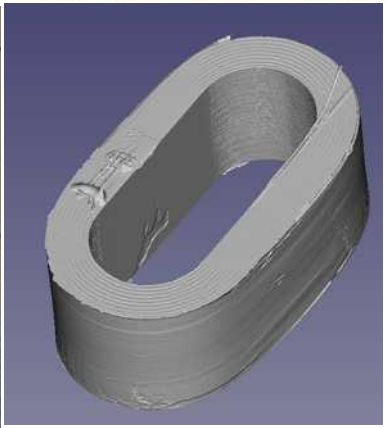
Winding House

- Winding house with access control
- Re-reeler with 2-3 m for reel-to-reel processes
- HTS winding table.
- LTS winding table
- Cu winding machines (workshop)
- 3D Scanning Metrology





Nb-Ti coil
(SLS2.0 superbend)



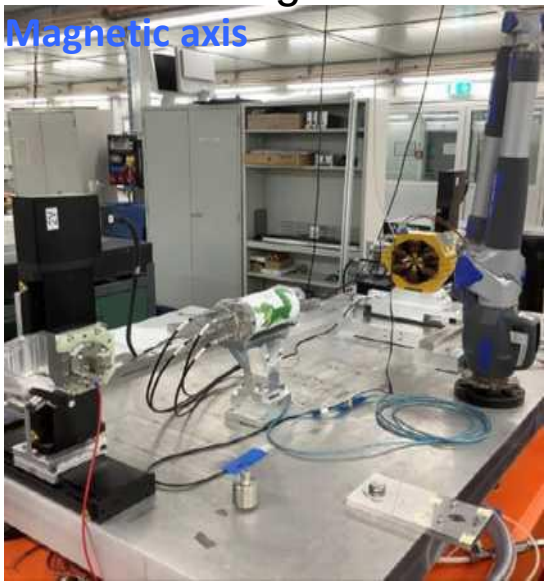
Magnet Lab : Measurement systems

Rotating coils

Multipoles

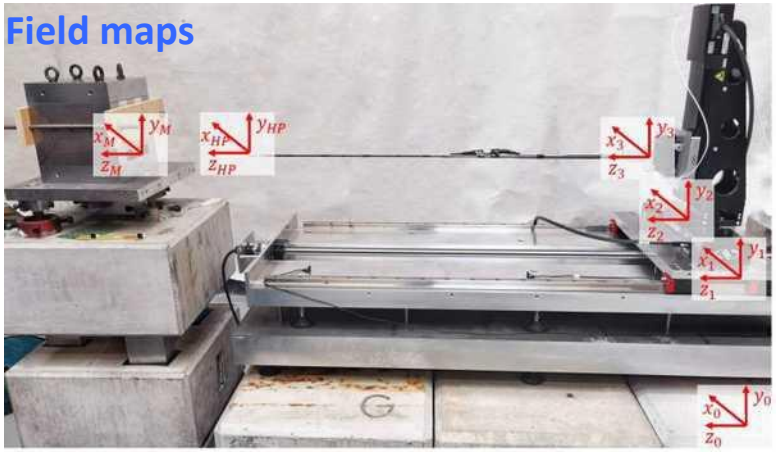
Vibrating wire

Magnetic axis



Field mapper

Field maps

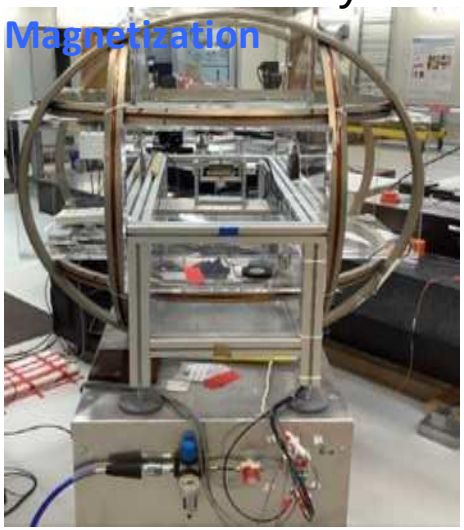


Moving wire

Field Integral

3D Helmholtz coil system

Magnetization

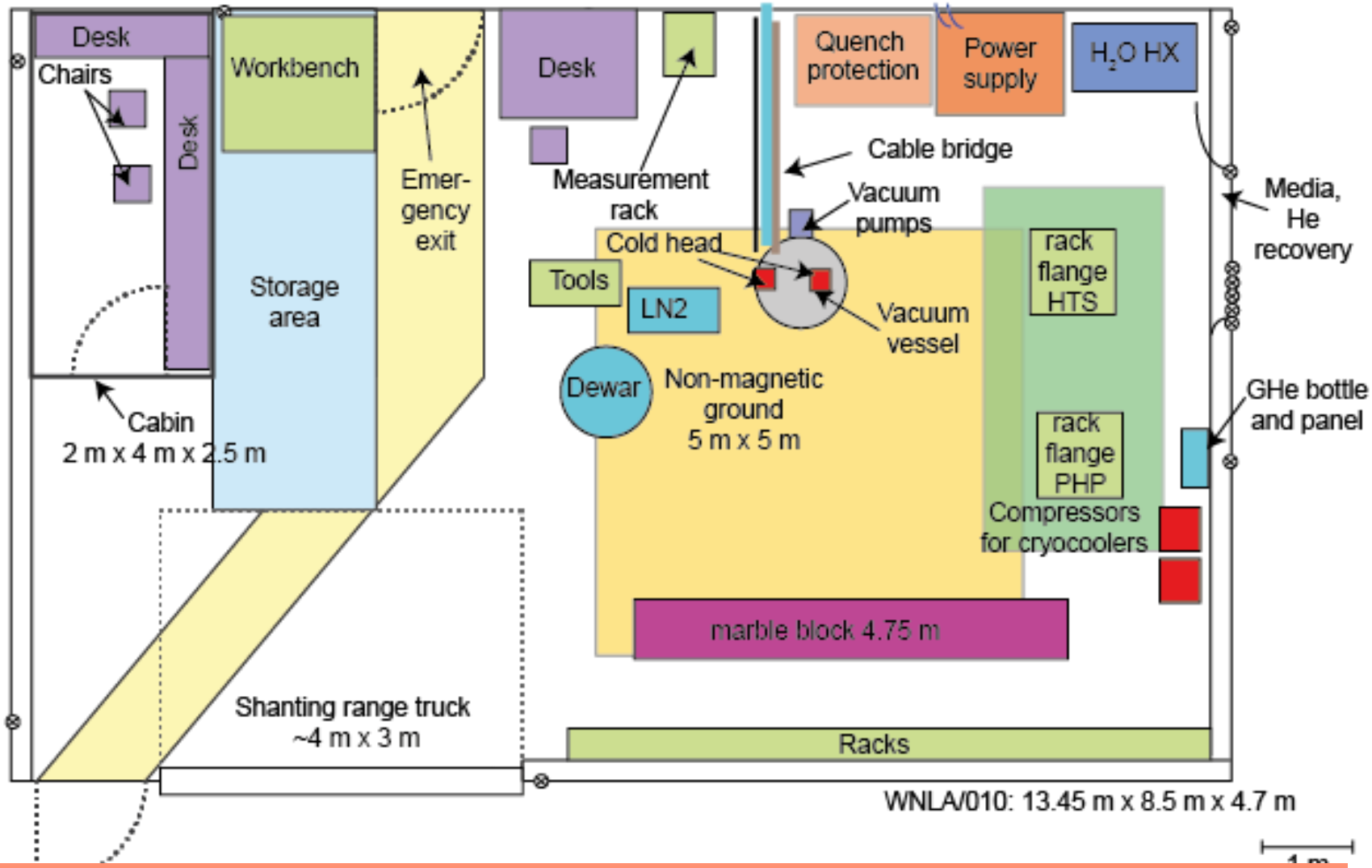


Accuracy : 1/1000

Reproduciblity : 1/10000

Axis : < 30 micrometers

2 kA cryogen-free test station at PSI



Multi-purpose facility for cryogen free superconducting elements and cryo R&D

10 kA upgrade in 2025 ?

2 kA cryogen-free test station at PSI

Aim (1) : Test of SC superbends (5T)+ HTS solenoids

2kA power converter

Electronic rack

- vacuum control
- temperature monitoring
- voltage signals recording
- quench detection system

Vacuum chamber

with pumps (not visible)

Radiation shield with MLI

Water chillers

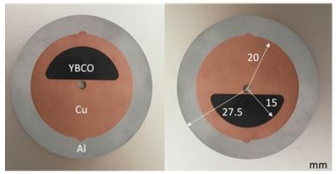
(for compressors and power converter)

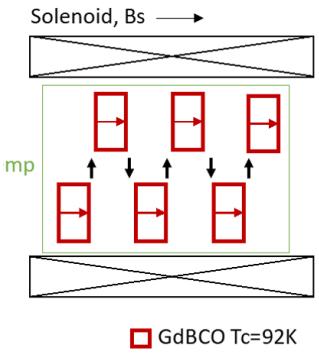
Cryostat insert with two cryocoolers

Power cables

(500A single cable)

Aim (2) : Test of HTS bulk undulator for iTOMCAT at SLS2





10 mm period, 4 mm gap, 2 T

Nb_3Sn solenoid : Fermilab

Bulk HTS sample : Cambridge

Some achievements in magnets and measurement systems

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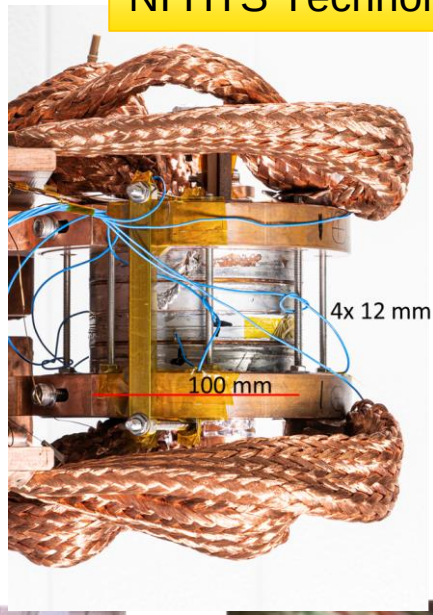
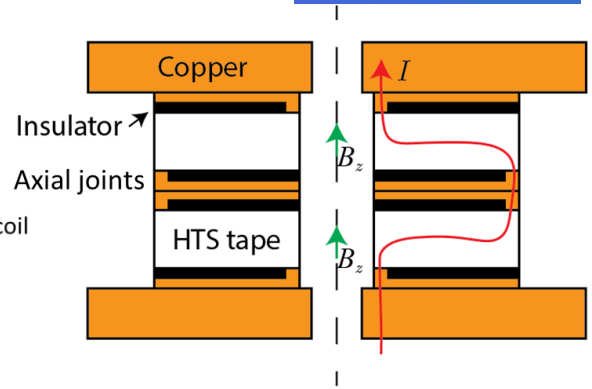
CHART Swiss Accelerator Research and Technology

PSI CCT magnet

NI HTS Technology Solenoid



tokamak energy a faster way to fusion

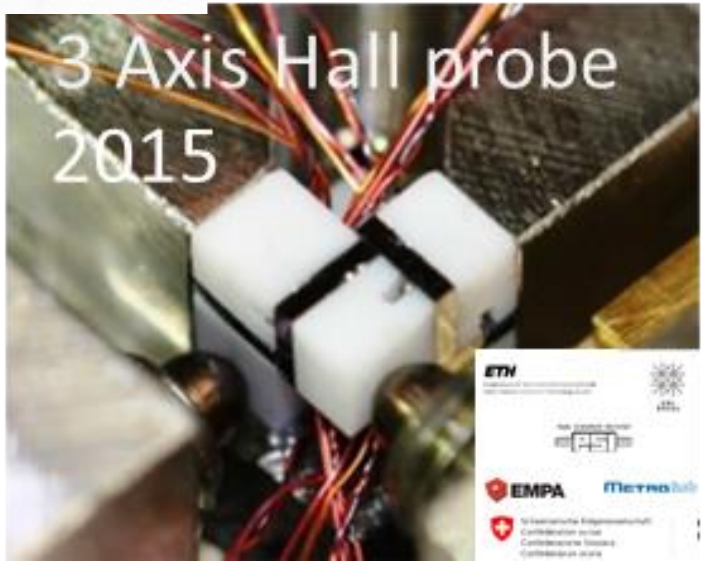


18 T at 12 K, 2 kA

Fluxmeter (ITER TF coil protype) 2016

PAUL SCHERRER INSTITUT PSI · iter · CERN · ASG Superconductors

3 Axis Hall probe 2015



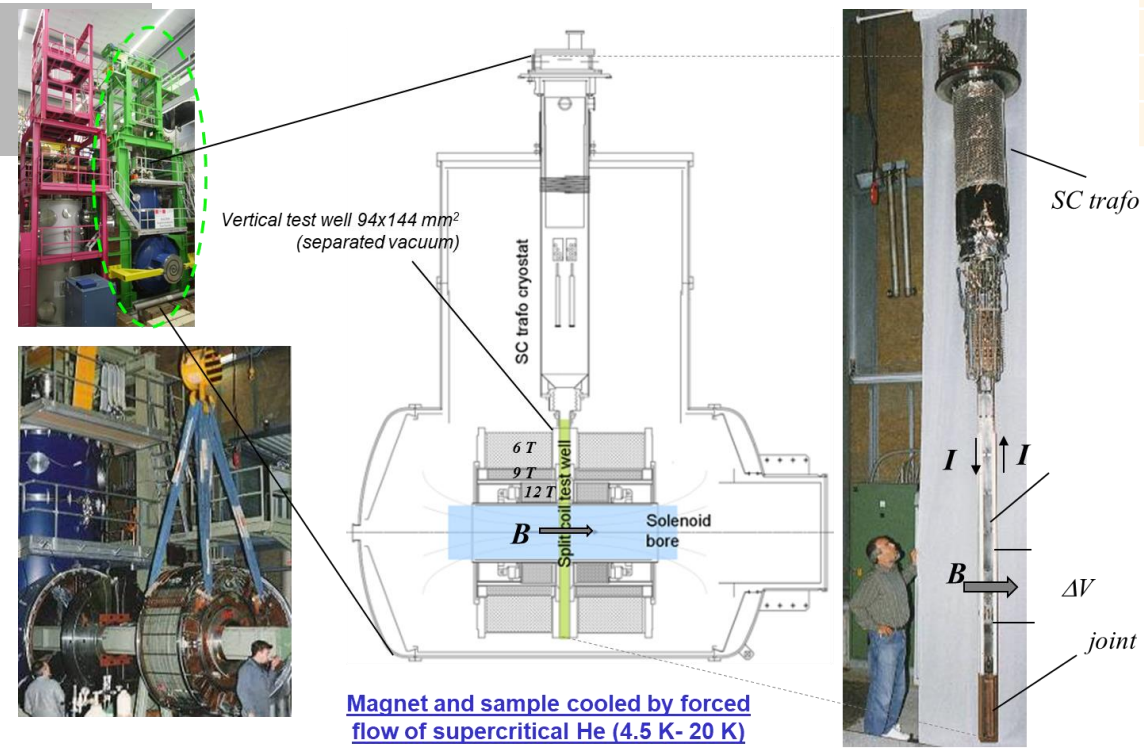
Magnet and cable test facility at the Swiss Plasma Center, EPFL (located at PSI, Villigen)

SWISS PLASMA CENTER

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

SULTAN- SUpraLeiterTestANlage

	SULTAN	EDIPO II
status	in operation	to be upgraded after accident
Magnetic field	11 T	15 T
Sample space	94x144 mm2	94x144 mm2
Temperature	4.5-50 K	4.5-50 K



Magnet and sample cooled by forced flow of supercritical He (4.5 K- 20 K)

Primary use of the SULTAN/EDIPO test facilities:

- Test of superconducting cables for fusion magnets (ITER, DEMO, etc.) up to 100 kA currents.
- Test of sub-size accelerator coils (e.g. “Feather” HTS magnets, R&D at CERN).
- Test of joints (fusion and accelerator cables).
- Quench experiments (only up to 15 kA).

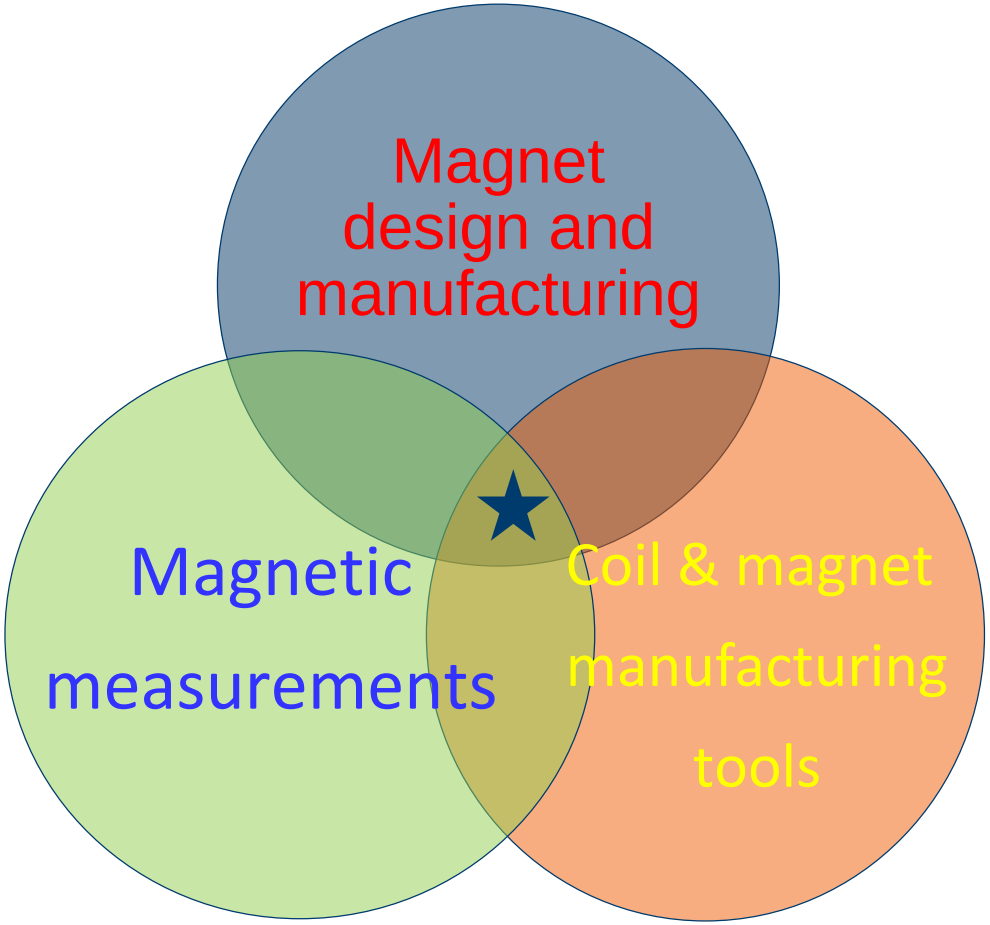
Facility for testing NbTi and Nb_3Sn CICC for ITER

(68 kA for the TF and 45.1 kA for the CS samples)

Testing of both LTS and HTS cables possible, in vacuum (forced-flow cooled conductors) or in He gas atmosphere (small magnets in a cryostat insert).

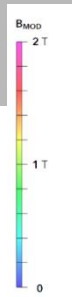
Courtesy K. Sedlak

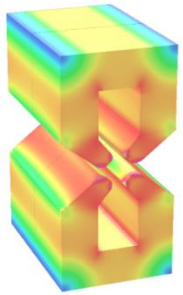
Magnet section & industry interaction

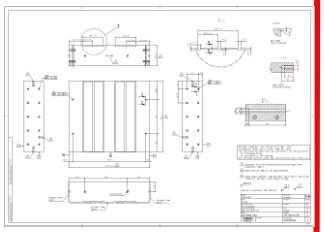


Magnet section & Manufacturer- approach used in the past

PSI

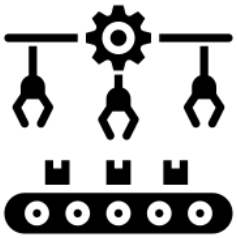


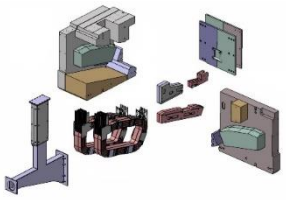




- Magnetic design
- Mechanical design
- Specification

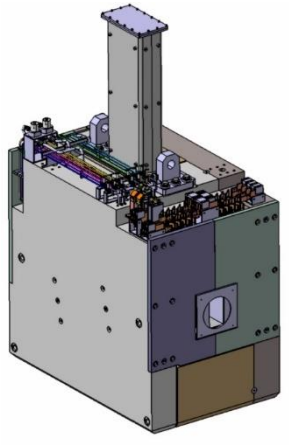
Manufacturer(s)





- Manufacturing

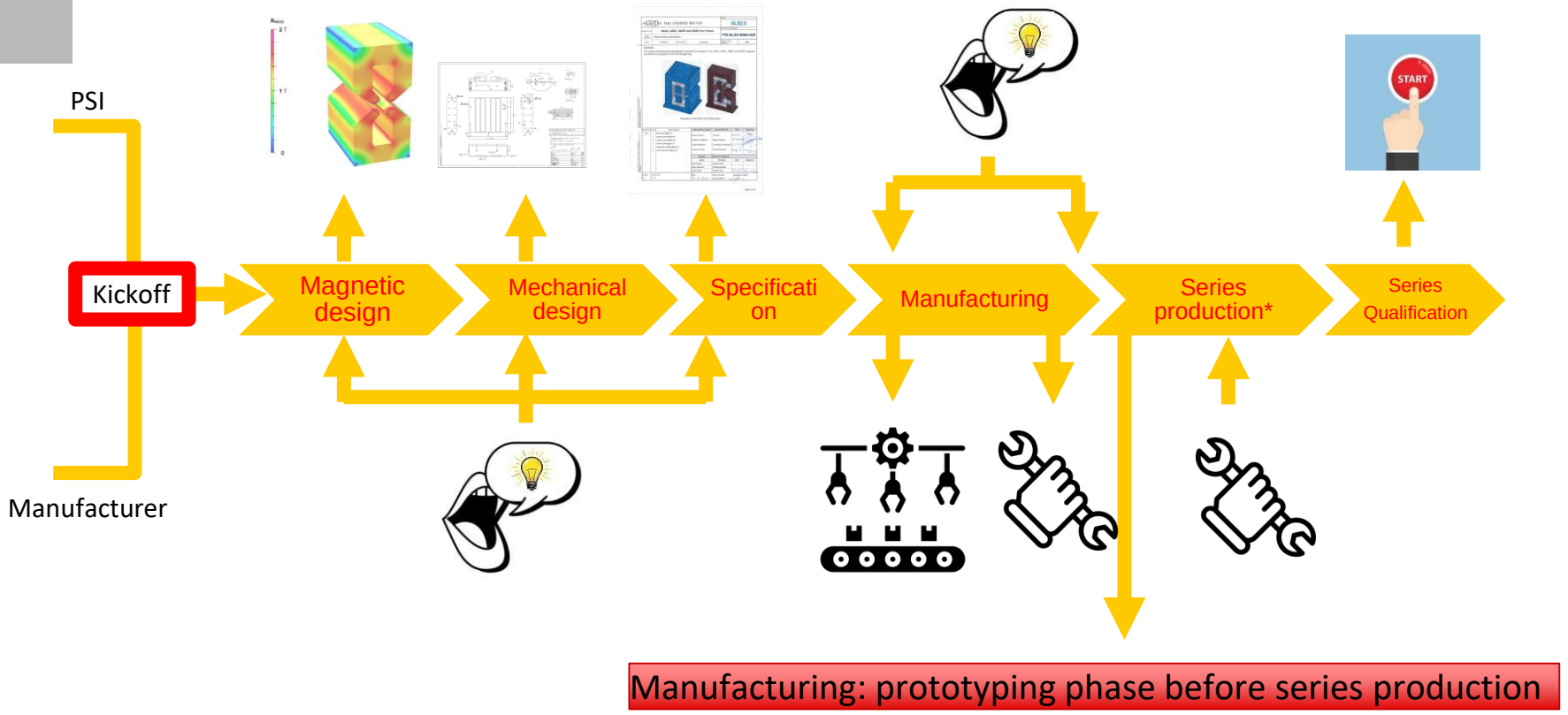
PSI



- measurements
- Commissioning

“build-to-print”

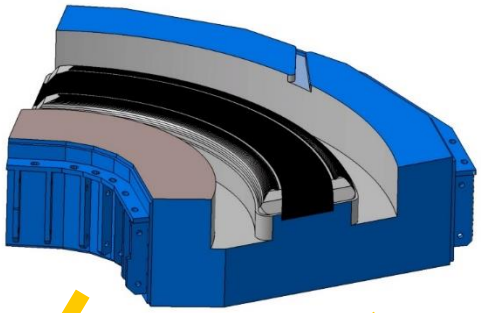
Magnet Section & Manufacturer- the future

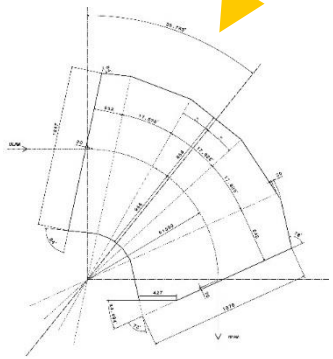


The industrial partner is involved in many steps of the development

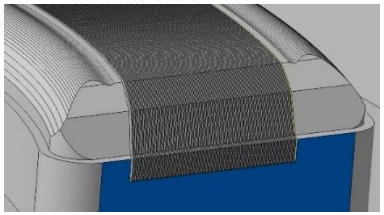
Some examples of collaboration in magnet manufacturing

Gantry 2: 90° Dipole





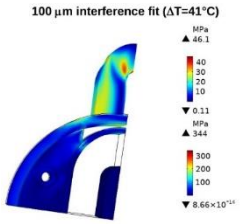
Segmentation for manufacturing



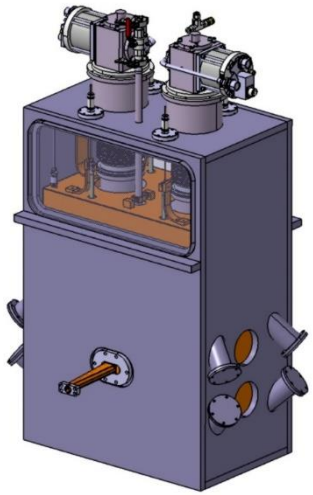
Special pole channel

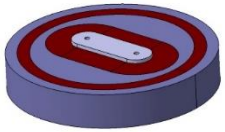
To reduce eddy currents

SLS 2.0 Superbend Magnet

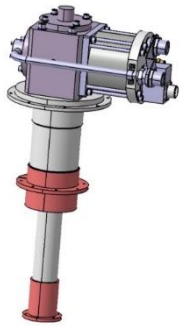


Design of coil precompression





Coil impregnation



mechanical integration of cryocooler

Conclusion

- Park Innovaare at PSI > opportunities in collaboration & innovation with Industry
- Large research Facilities opened to companies
- Magnet technology : Competence center and facilities for magnets of all types and insertion devices
- Magnet section & industry : from “build-to-print” to co-development

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Thank you for your attention

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