EUROPEAN SPALLATION SOURCE

The first long spallation source (ESS) and continuous spallation source (PSI)

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for
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Science Drivers for Spallation Sources

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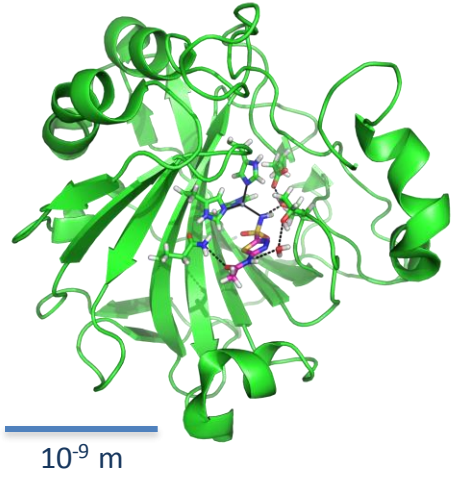
- chemistry of materials
- archeology & heritage conservation
- life sciences
- magnetism & superconductivity
- energy research
- fundamental & particle physics
- soft condensed matter
- engineering & geo-sciences

Example: Better drugs from detailed protein maps

This enzyme transports CO_2 and regulates blood pH and is a major player in some cancers, glaucoma, obesity and high blood pressure. Neutron crystallography pinpoints protons and waters, showing how the drug Acetazolamide binds.

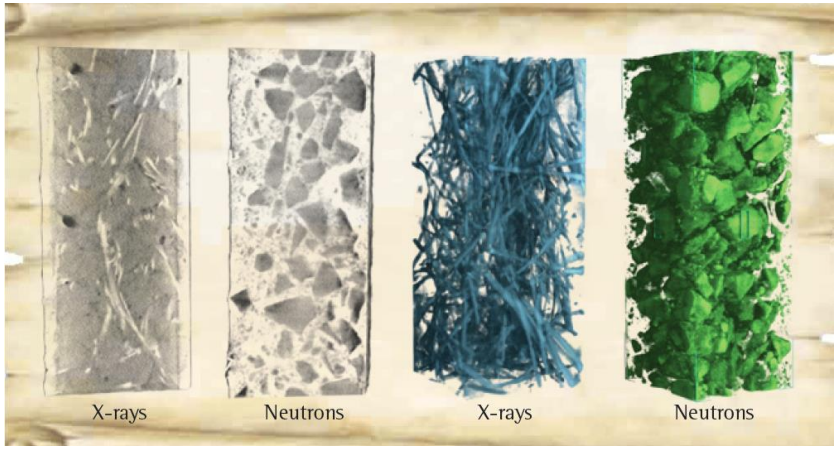
Source: Fisher, S. Z. et al. 2012 JACS



Example: Engineering materials

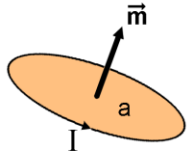
Non-destructive analysis of a steel armed concrete block with neutron imaging and X-ray tomography.

Source: PSI, CEMNET workshop 2007



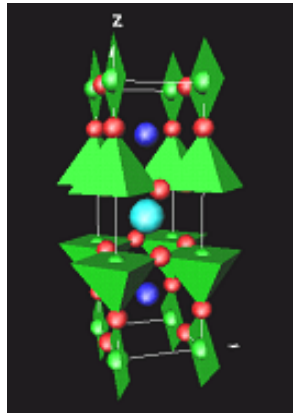
Neutrons well suited as probe !

Wave Particle Magnetic moment Neutral



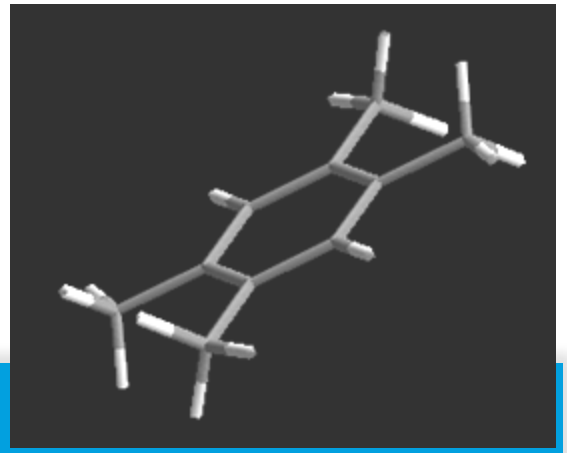
Diffractometers - Measure structures
- Where atoms and molecules are

1 - 10 Ångström



Spectrometers - Measure dynamics
- What atoms and molecules do

1 - 80 meV



Spallation* sources

Spallation sources come in at least three types of time structures:

- short pulse sources (a few μs) -> ISIS, JPARC, SNS
- long pulse sources (a few ms) -> **ESS**
- continuous sources -> **PSI**

In general, synchrotrons or accumulator (compressor) rings provide short neutron pulses, linear accelerators provide long neutron pulses, and cyclotrons provide continuous beams of neutrons.

Table 11.11. The number of fast neutrons produced per joule of heat energy where the energy in joule is taken as heat produced over energy consumed. [2].

Fission reactors	$\sim 10^{9}$	in ~ 50 liter volume
Spallation	$\sim 10^{10}$	in ~ 1 liter volume
Fusion	$\sim 2\times10^{10}$	in huge volume
Photo neutrons	$\sim 10^{9}$	in ~ 0.01 liter volume
Nuclear reaction (p, Be):	$\sim 10^{8}$	in ~ 0.001 liter volume
Laser induced fusion	$\sim 10^{4}$	in $\sim 10^{-9}$ liter volume

* In nuclear physics, spallation is the process in which a heavy nucleus emits a large number of nucleons as a result of being hit by a high-energy particle, thus greatly reducing its atomic weight

Neutron evolution

- Many of the reactor based neutron sources are being phased out = decline in the availability of neutrons = decline in competence and competitiveness
- The vast majority of users will profit from a pulsed structure
  - Existing short pulse sources (ISIS, JPARC and SNS) can supply the present and imminent future need of short pulse users
  - A large fraction of users are fully satisfied by a long pulse source
  - Long pulse for physics flexibility (cold and thermal neutrons available)

(Updated from *Neutron Scattering*, K. Skold and D. L. Price, eds., Academic Press, 1986)

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ESS is located in a larger research setting

The road to realizing the world's leading facility for research using long pulse neutrons

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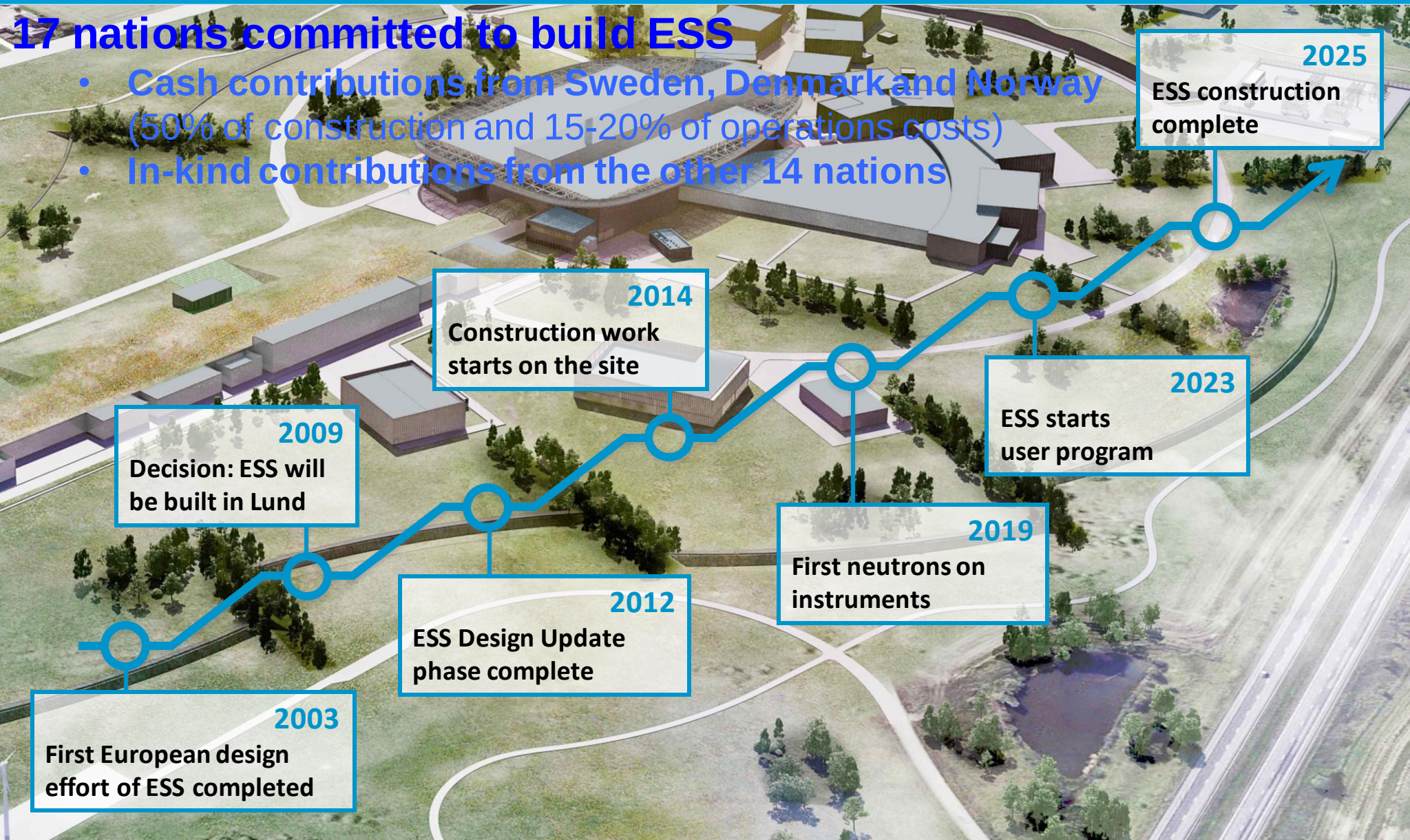

Accelerator Selected technologies

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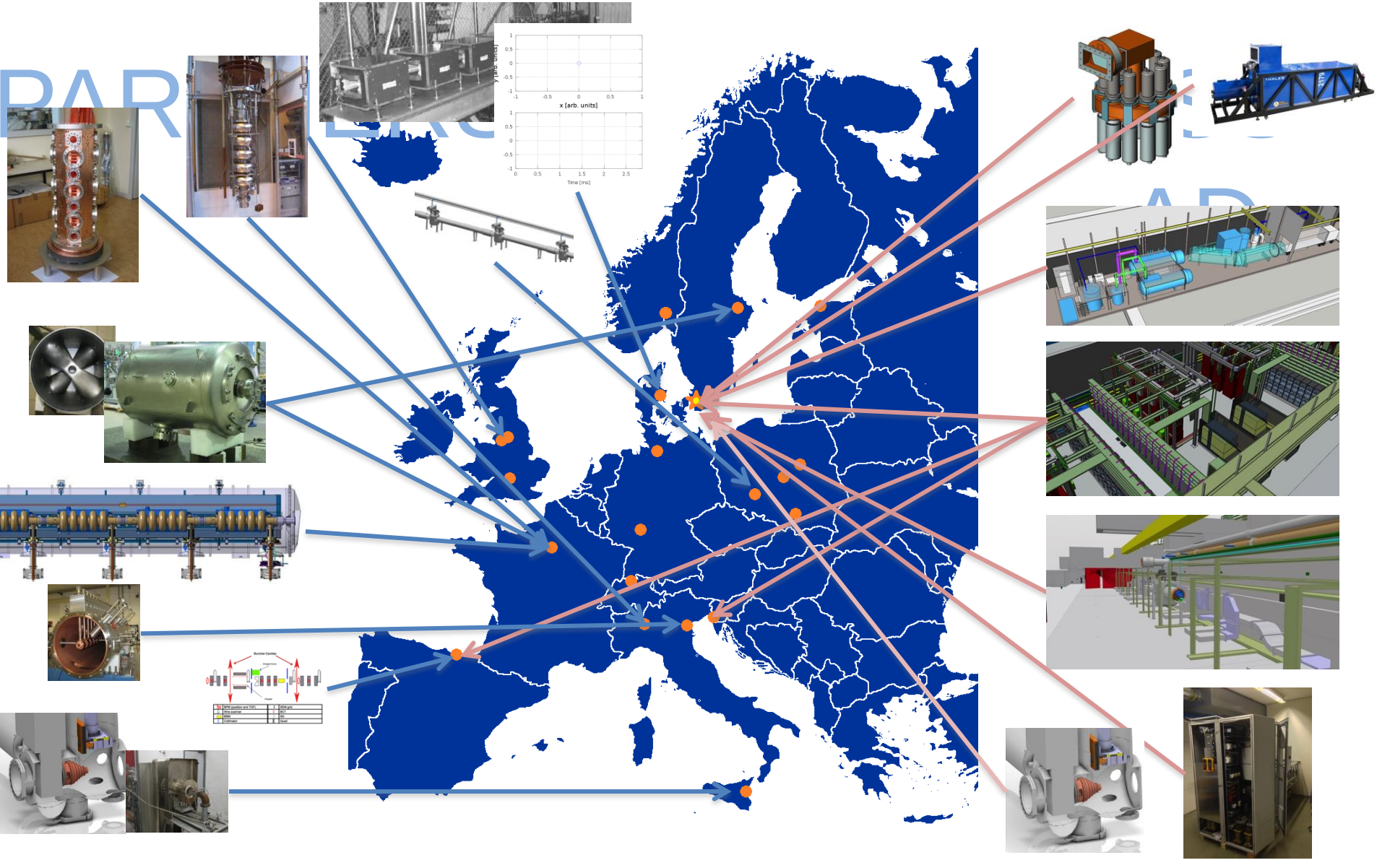


Update from the ESS site

Accelerator Technical performances

Design Drivers:

High Average Beam Power

5 MW

High Peak Beam Power

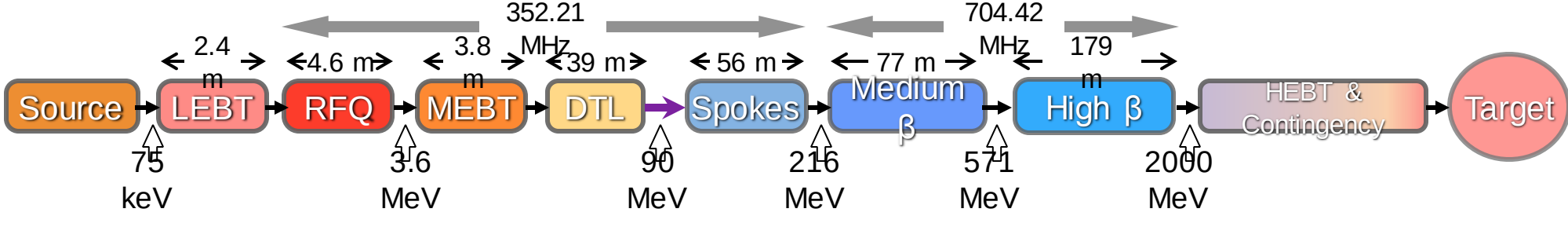
125 MW

High Availability

> 95%

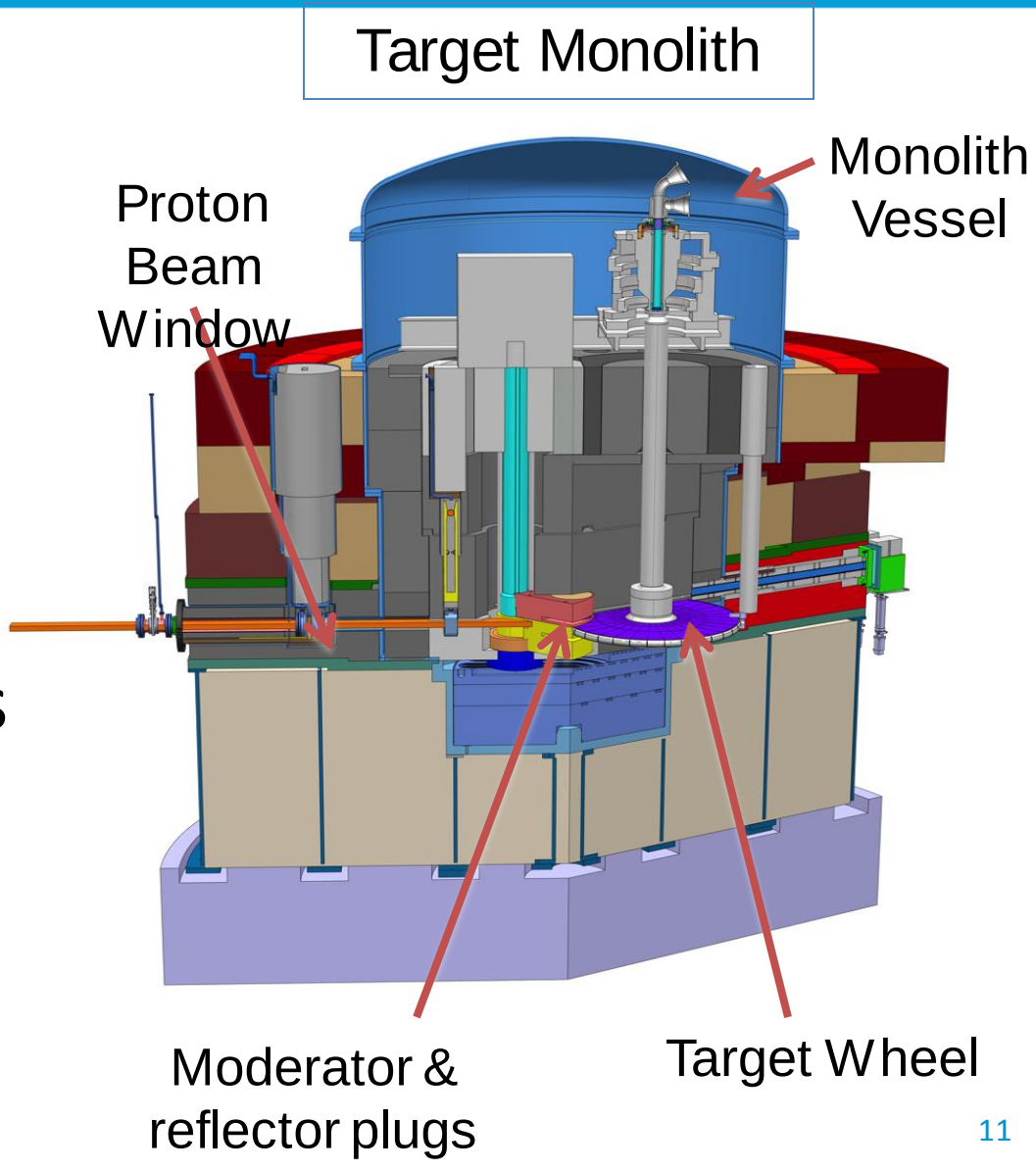
Key parameters:

- -2.86 ms pulses
- -2 GeV
- -62.5 mA peak
- -14 Hz
- -Protons (H+)
- -Low losses
- -Minimize energy use
- -Flexible design for mitigation and future upgrades



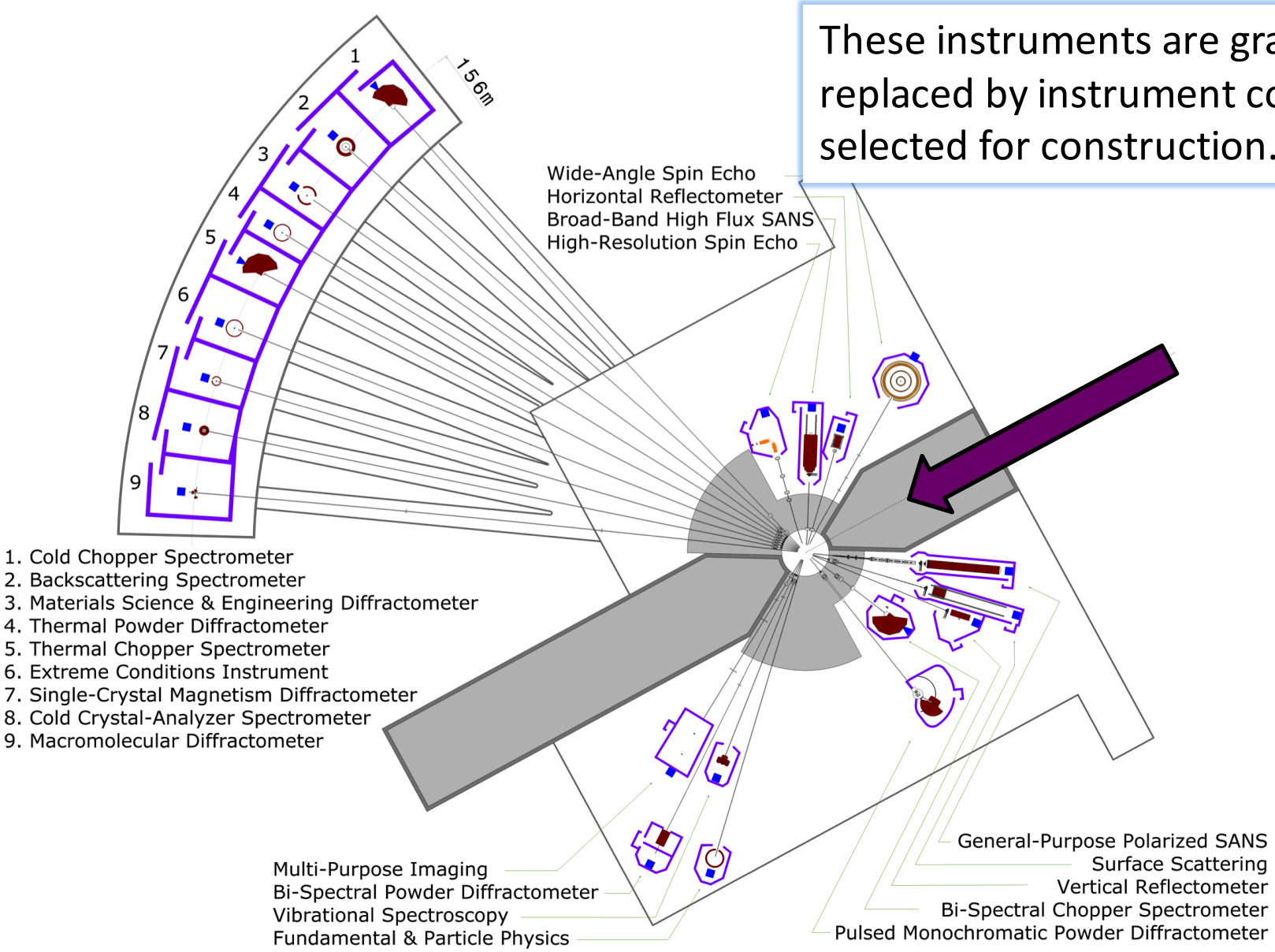
Target Station incorporates unique features

- Rotating W target
- He gas cooling for target
- High brightness neutron moderators



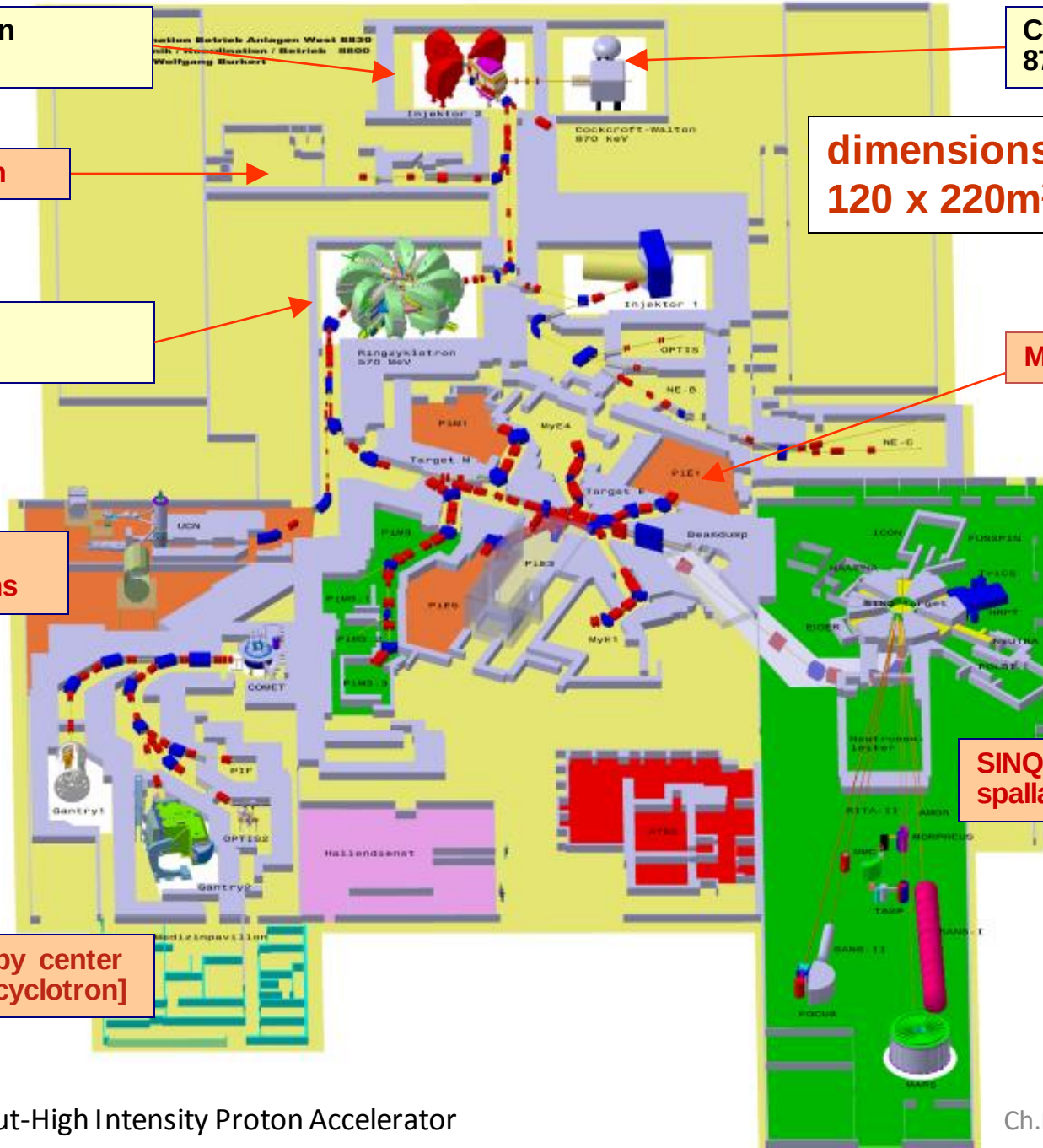
The reference suite – a guide

These instruments are gradually being replaced by instrument concepts selected for construction.



Overview PSI-HIPA*

slides provided by Ch.Rüegg, M.Seidel/PSI



Injector II Cyclotron
72 MeV, 160kW

Cockcroft Walton
870keV, 10kW

Isotope Production

dimensions:
120 x 220m²

Ring Cyclotron
590 MeV, 1.3MW

Muon Beamlines

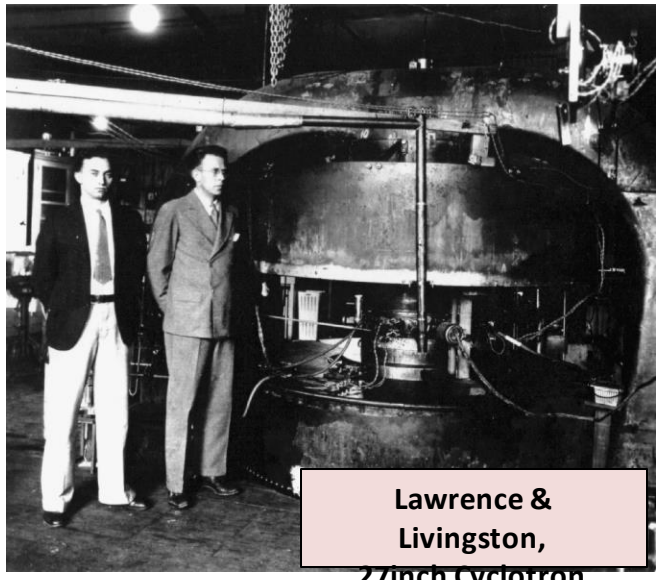
UCN
Ultra-Cold Neutrons

SINQ
spallation source

proton therapy center
[250MeV sc. cyclotron]

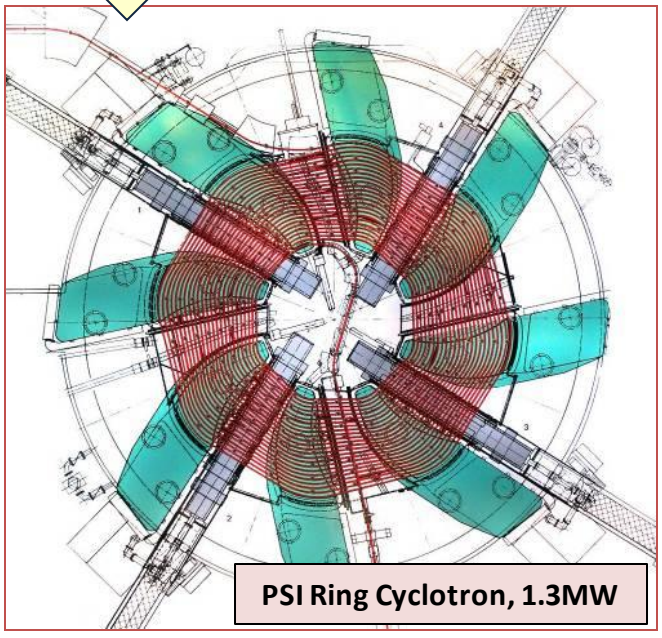
* Paul Scherrer Institut-High Intensity Proton Accelerator

PSI-HIPA: Why Cyclotrons ?



Lawrence & Livingston, 27inch Cyclotron

AVF focusing
Ring, separated magnets

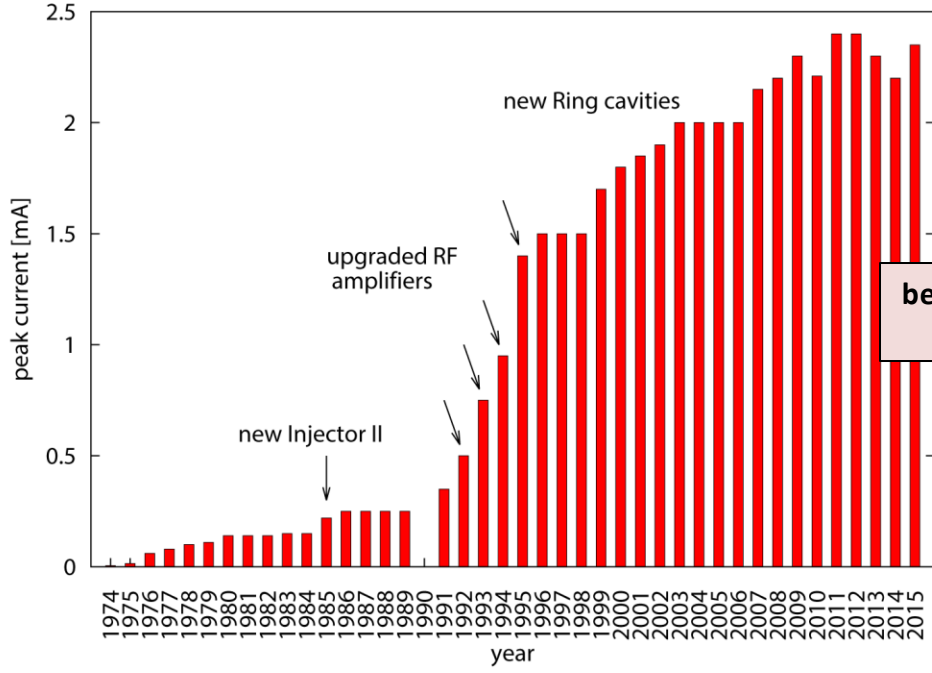


PSI Ring Cyclotron, 1.3MW

Advantages:

- continuous acceleration, low losses 10^{-4}, high beam power possible
- repetitive use of resonators, compact and cost effective
- high energy efficiency (PSI RF, Grid-to-beam: 32%)

→ These arguments hold also today, 80 years after the invention of the concept.



beam intensity history

PSI-HIPA: Secondary Particles

- **Muons:** Graphite targets 5/40mm; max: **$5 \cdot 10^8 \mu^+/s$**; p =28MeV/c; $\Delta p/p = 9.5\%_{FWHM}$; $\varepsilon_{x/y} = 5/10 \cdot 10^{-3}$m·rad

  T. Prokscha, et al., Nucl. Instr. and Meth. A (2008), doi:10.1016/j.nima.2008.07.081

- **Neutrons:** water-cooled solid lead target; CW - not pulsed!; flux typically **1/10…1/2 × ILL(reactor);** at source ≈10^{13} n/s·cm^2; at exp. ≈$10^{8..9}$ n/s·cm^2; monochrome ≈$10^{5..6}$ n/s·cm^2;

  $\lambda_{cold} \approx 3…20$ Å; $\lambda_{therm} \approx 0.8…2.5$ Å

Spallation Neutron Source SINQ - Science

Magnetic and atomic structures
Neutron diffraction

Elementary excitations
Neutron spectroscopy

Large-scale structures
Neutron SANS and reflectometry

Applied science
Neutron imaging

Research on Materials for …

Energy storage: battery materials, materials for H-storage
Energy conversion: fuel-cell membranes

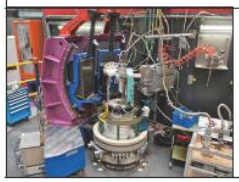
Information technology: molecular magnets, magnetic thin films, nano-structured materials
New technologies: superconductors, multiferroics, soft matter, metals, ceramics, metal foams, ionic liquids

Health care: membrane structures, novel drug delivery systems, food science

Spallation Neutron Source SINQ - Instruments

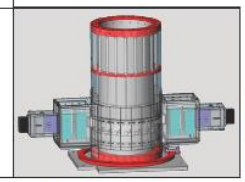
Diffraction | Spectroscopy | SANS + Ref. | Imaging

TriCS | HRPT | NEUTRA | POLDI | MORPHEUS | AMOR | MuPAD







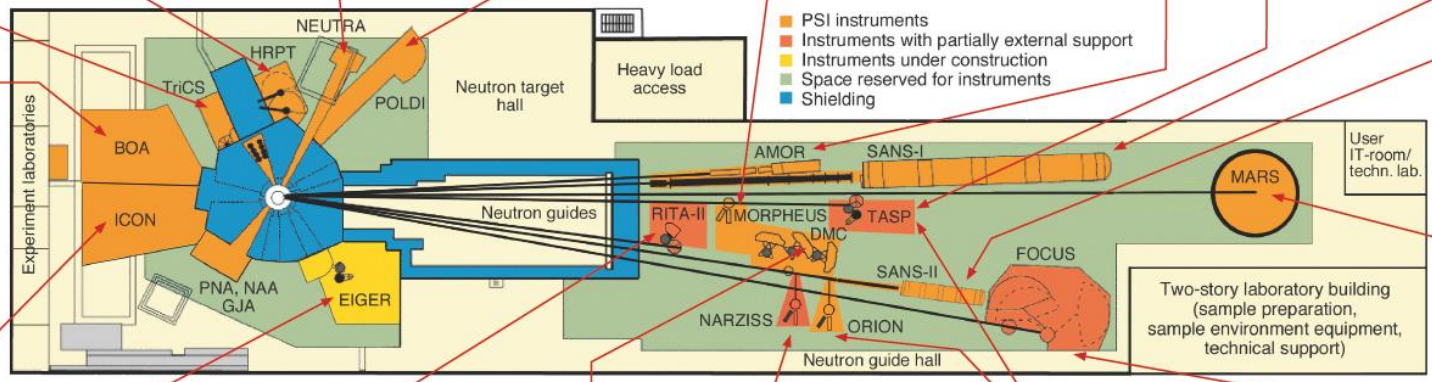



SANS-I

SANS-II

MARS

BOA







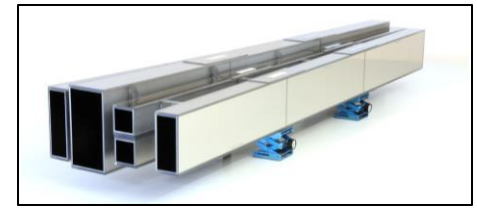



ICON | EIGER | RITA-II | DMC | NARZISS | ORION | TASP | FOCUS

Spallation Neutron Source SINQ - Upgrade

Neutron Source

Reliable operation of HIPA and SINQ (95%)

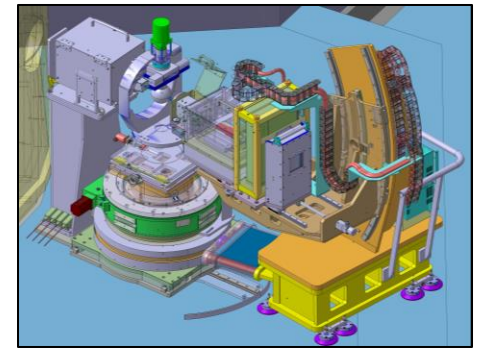


Neutron Optics

Optimized beam extraction, neutron transport and focusing
Only useful neutrons are transported, optimum focusing, signal-to-noise
Comprehensive upgrade of super-mirror neutron guide system

New Instruments and Major Instrument Upgrades

Modernization and upgrade projects:
Small samples and extreme conditions



1) Small sample, extreme conditions spectrometer (**CAMEA**)
2) Small sample single-crystal diffractometer (**ZEBRA**)
3) High-resolution neutron microscope (**N-Microscope**)

1) Fully focusing reflectometer on dedicated guide (**SELENE**)
2) Extreme conditions instrument for high-fields and pressure (**Xtreme**)
3) Optimized small sample SANS (**SANS-X**)

Thank you for your attention!