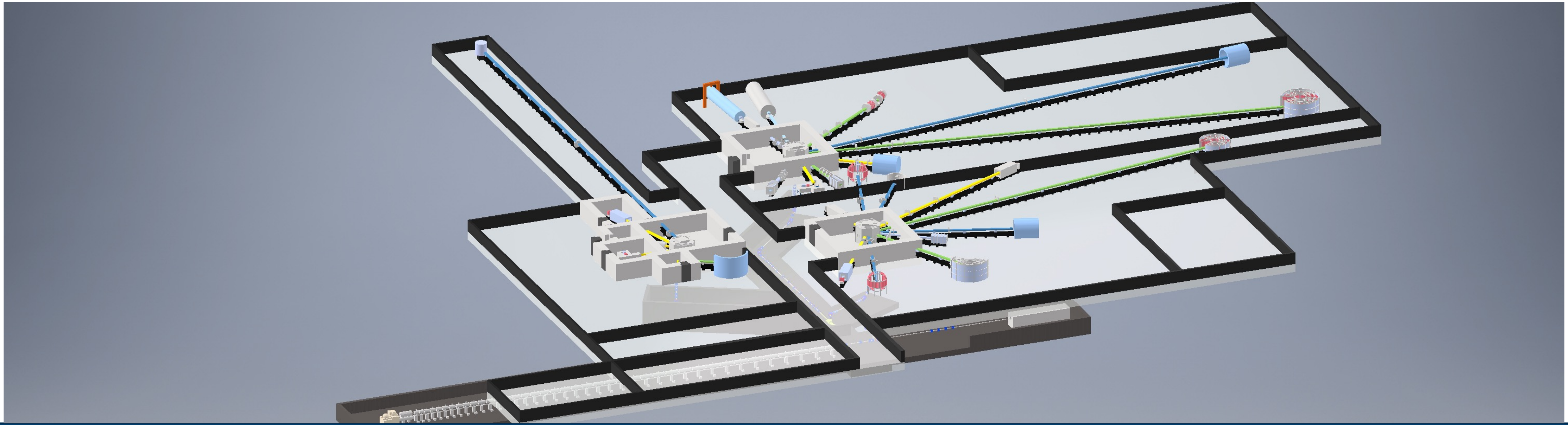


# HBS - JULIC Neutron Platform

## A testbed for the development of the High Brilliance neutron Source HBS

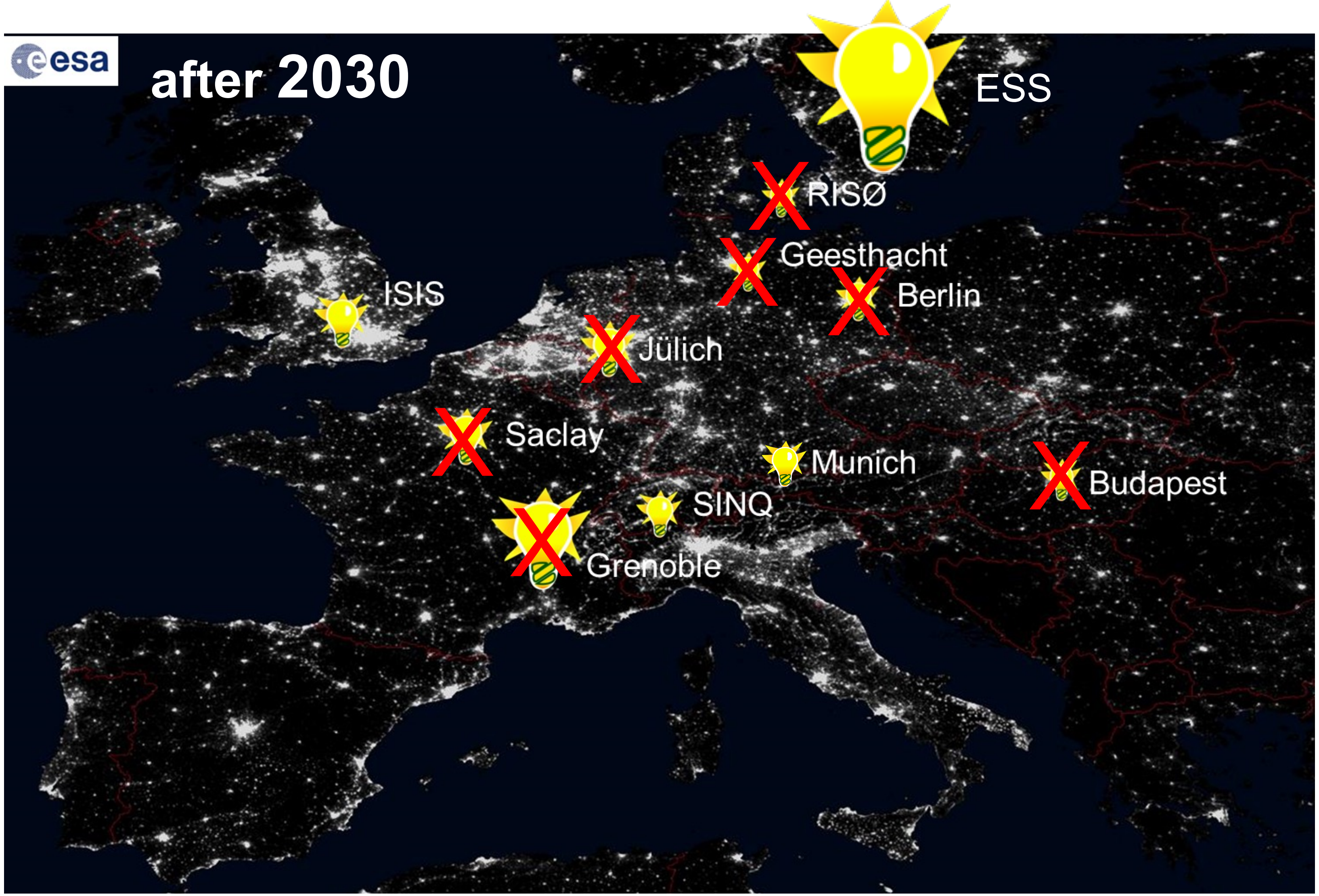
FEB 23, 2023 I THOMAS BRÜCKEL & PAUL ZAKALEK FOR THE HBS TEAM

Mitglied der Helmholtz-Gemeinschaft

JÜLICH Forschungszentrum

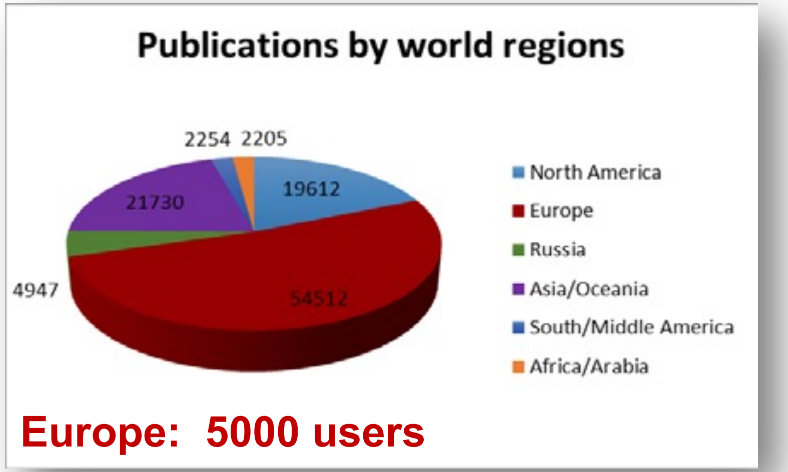
# OUTLINE

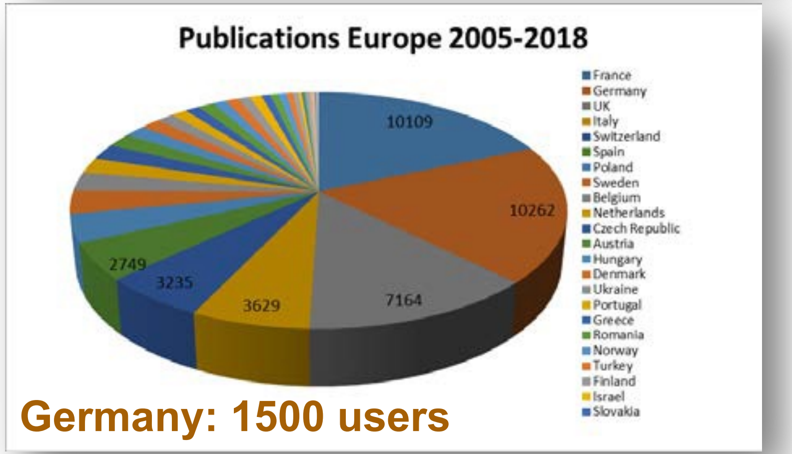
# DRASTIC CHANGES IN EUROPEAN NEUTRON LANDSCAPE

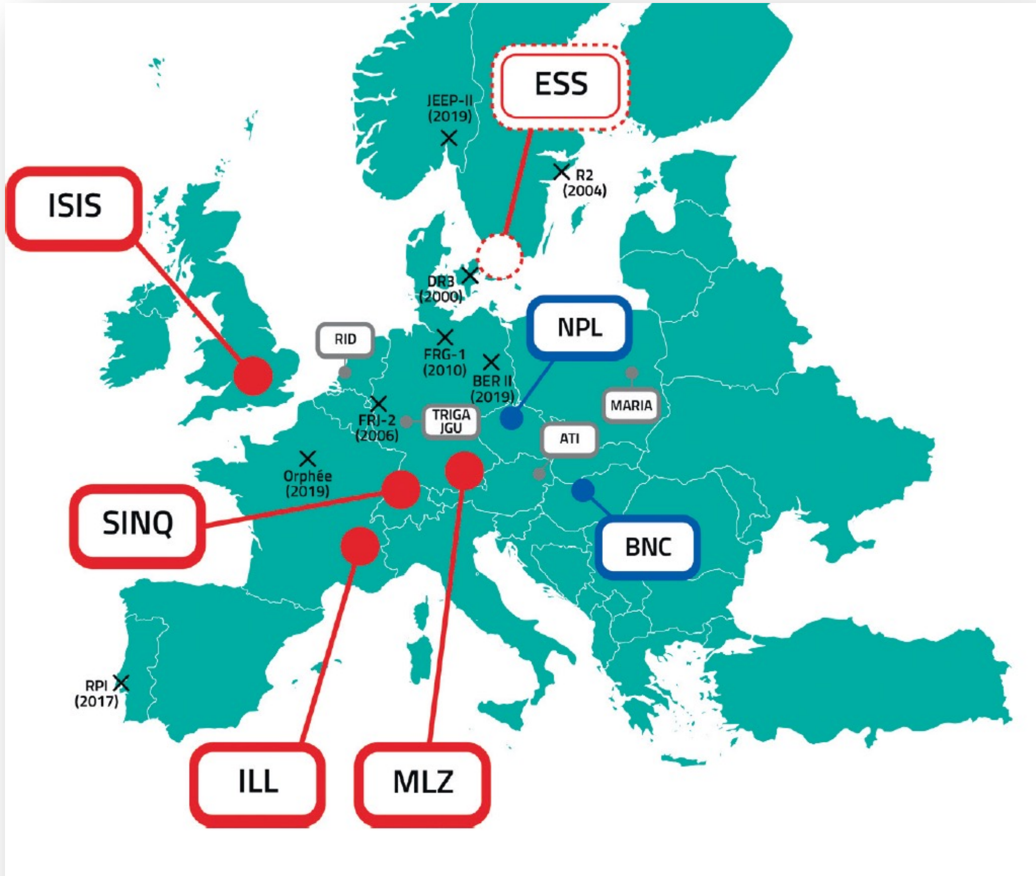


# EUROPEAN ECOSYSTEM 2030+: VULNERABLE!

## Few major facilities for a leading community of 5000 users → vulnerable, capacity limited



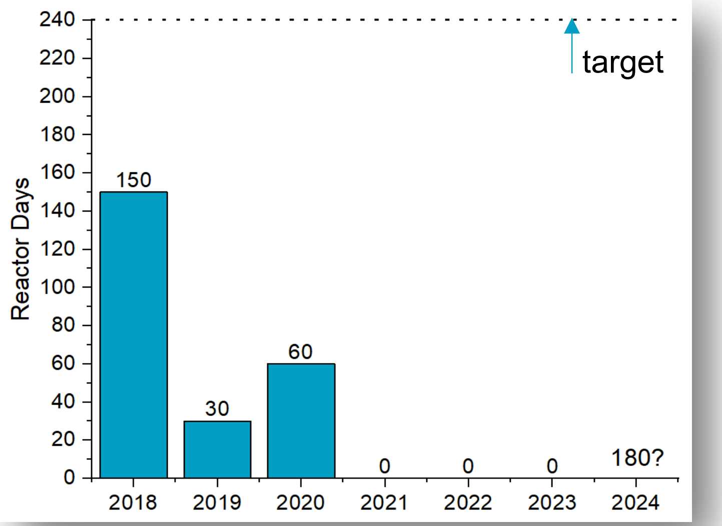

Neutron facilities in Europe. Larger facilities shown in red. Dashed lines indicate a facility that is under construction. Facilities that are no longer operating are marked with an x. © LENS - Stephanie Chapman

# VULNERABILITY: RESEARCH REACTOR BASED SOURCES!

## FRM II: Leak in central channel, broken cold source

German national source FRM II:

- no neutrons since 3 years, restart planned for 2024
- cold source operational earliest 2025
- already one generation of PhD students lost !




→ resilient accelerator-based neutron facilities:

Compact Accelerator-driven Neutron Sources CANS
High Current Accelerator-driven Neutron Sources HiCANS

# CANS & HiCANS FOR A SUSTAINABLE ECOSYSTEM!

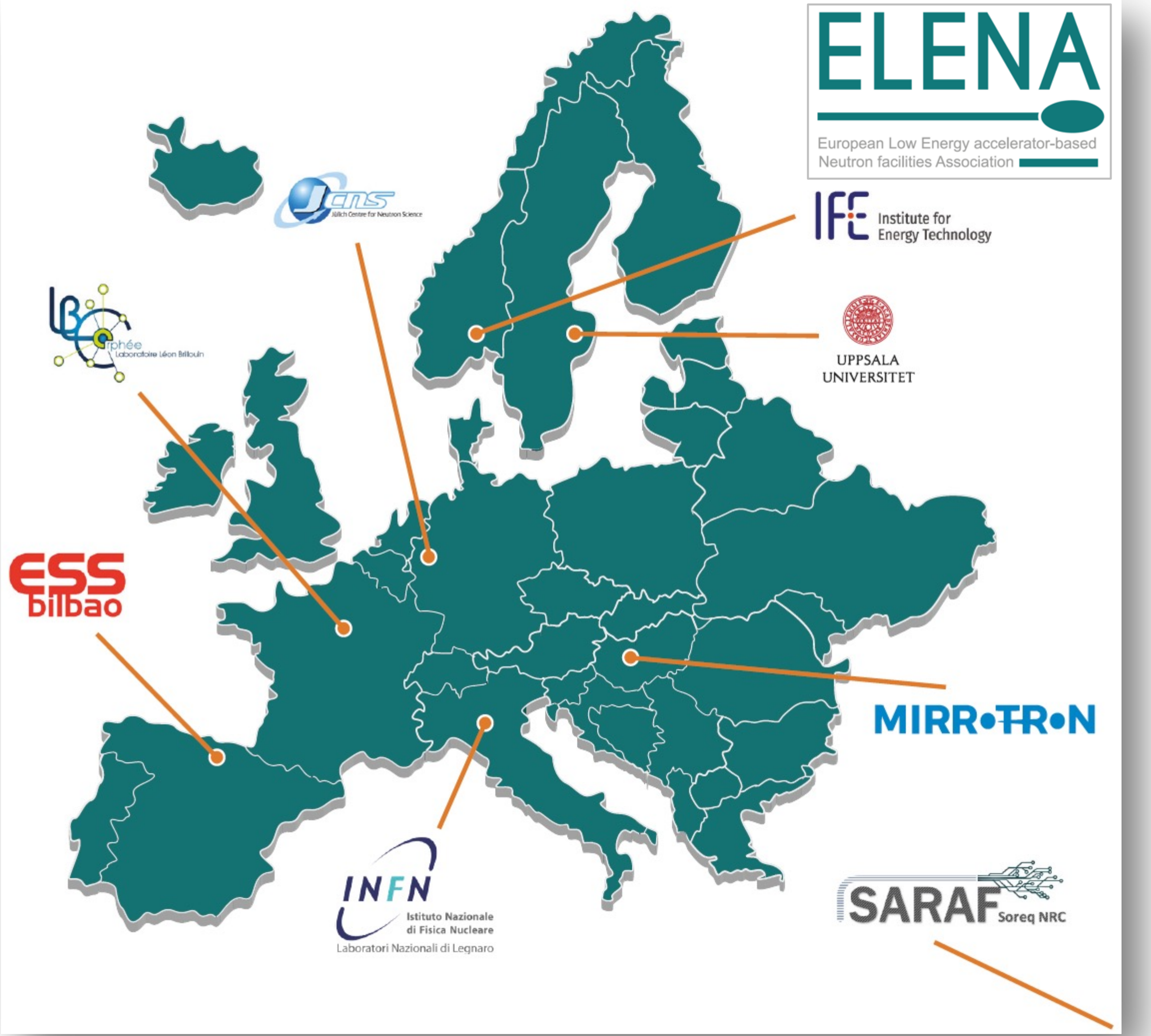
## Projects within the European Low Energy accelerator-based Neutron facilities Association (ELENA)

CANS:  Compact Accelerator-driven Neutron Sources
HiCANS: High Current Accelerator-driven neutron Sources

LENS LEAGUE OF ADVANCED EUROPEAN NEUTRON SOURCES

- Though ESS will provide enhanced capabilities, these can only be fully exploited if the supporting ecosystem has sufficient strength, depth and diversity.
- The only route for entirely new facilities with significant capacity are High Current Accelerator-driven Neutron Sources …

HiCANS do not exist yet worldwide
HBS:  first and most ambitious HiCANS project





JÜLICH Forschungszentrum

# OUTLINE

- Motivation: Changing European Neutron Landscape
- **The HBS Project: the HiCANS Technology Leader**
- JULIC Neutron Platform: a testbed for HBS
- Proposed beamtimes
- Summary

# HBS: THE NEXT-GENERATION NEUTRON FACILITY

## A national neutron facility for science and industry with unique selling points

breaking with seemingly well-established certainties; based on fresh thinking!

| | |
|---|---|
| **a highly efficient neutron facility** | offers cost-efficient neutron provision for highly competitive instruments<br>*low energy accelerator, small target, compact shielding* |
| **changes the paradigm of neutron facilities** | the source becomes integral part of the instrument<br>*with optimized pulse structure, spectrum & beam extraction* |
| **sustainable & accessible** | minimizes radioactive waste and requires no nuclear licensing<br>*easy access for users from science and industry* |
| **opportunities for innovation and technology** | novel technologies and attractive access schemes<br>*innovation during construction and operation* |
| **resilient & flexible** | modular design, can be adapted to specific requirements<br>*minimizes down times, flexible set-ups* |

# COMPETITIVE INSTRUMENTS BY FACILITY DESIGN

## HBS: A High Current Accelerator-driven Neutron Source (HiCANS)

**high current accelerator → HiCANS**

- 100 mA, 70 MeV for increased source strength
- adapted macro bunch filling pattern

**several target stations**

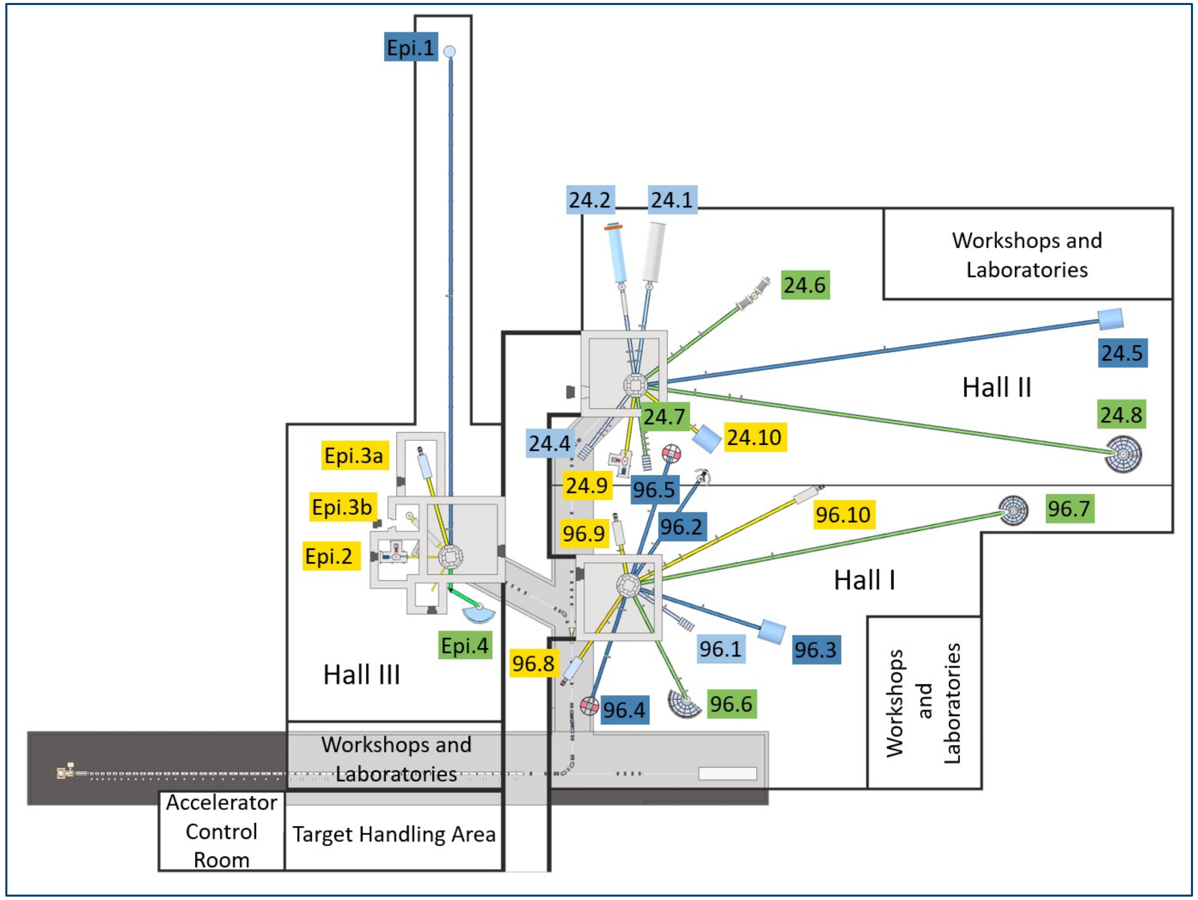
- served by multiplexer
- optimized pulse structure (length, frequency)

**every beam port serves only 1 Instrument**

- optimized source spectrum and geometry
- neutron optics integrated in beam port

**compact shielding → optimal neutron optics**

- optical elements positioned close to moderator
- optimal phase space extraction



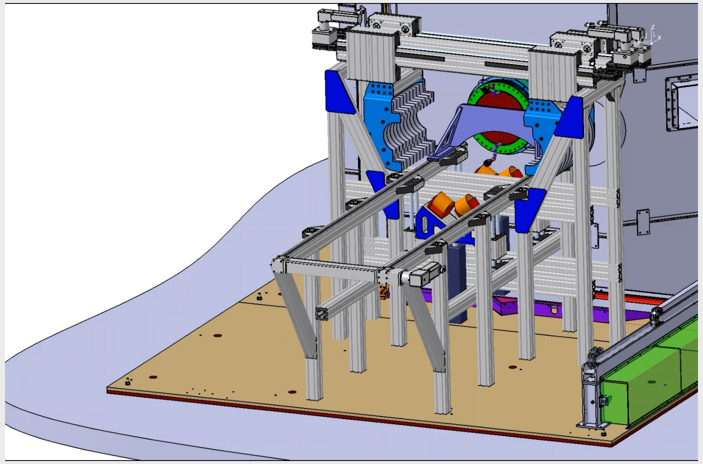
# HBS: A RESILIENT FACILITY WITH MODULAR DESIGN

## Reliability: Minimizing downtimes due to easy exchange of critical components

### Accelerator

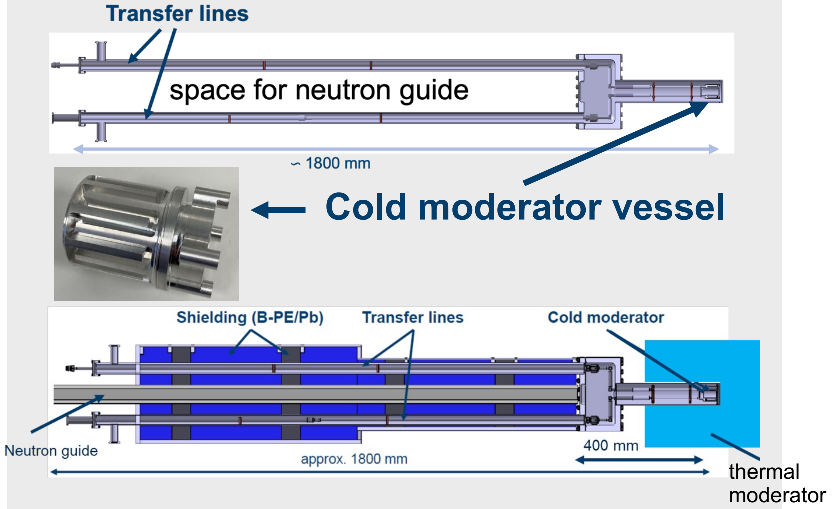
Solid state amplifiers can be easily exchanged.

### Target



Target exchange with fully automized handling tool.

### Cold Moderators




only one instrument affected; insert can be pulled out from outside the TMR and replaced.

**no dependence on supply of regulated material, easy exchange due to modular design**

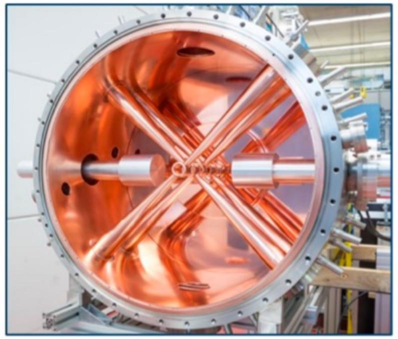
# ✓ DRAFT FOR 2 VOLUMES FINISHED

## Technical Design Report (TDR) in 4 Volumes plus Summary

### TDR Accelerator

Executive editors:

H. Podlech (IAP Frankfurt)
A. Lehrach (IKP-4)
R. Gebel (IKP-4)

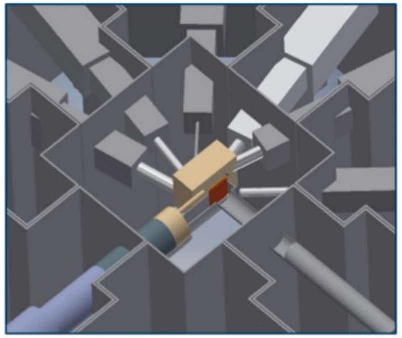


100 %

### TDR Neutron Target

Executive editors:

P. Zakalek (JCNS-HBS)
J. Baggemann (JCNS-HBS)
U. Rücker (JCNS-HBS)
E. Mauerhofer (JCNS-HBS)

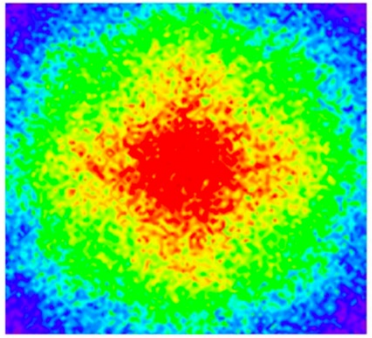


85%

### TDR Neutron Instruments

Executive editors:

J. Voigt (JCNS-IT)
K. Lieutenant (JCNS-IT)

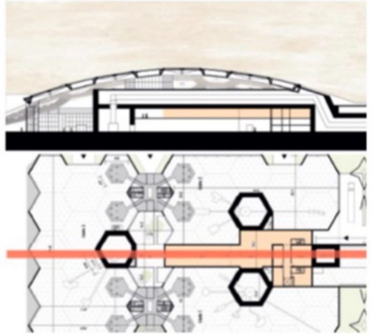


100 %

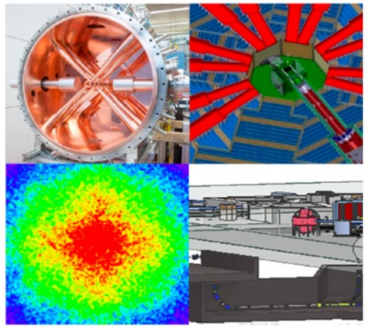
### Infrastructure & Sustainability

Executive editors:

C. Claudio-Weber (JCNS)
T. Gutberlet (JCNS-HBS)



70%



Technical Design Report HBS
Preliminary Summary

T. Brückel, T. Gutberlet (Eds.)

J. Baggemann, Y. Beßler, T. Claudio-Weber, J. Fenske, H. Frielinghaus, C. Franz, A. Glavic, R. Hanslick, S. Jaksch, H. Kleines, J. Li, A. Lehrach, K. Lieutenant, E. Mauerhofer, O. Meusel, S. Pasini, I. Pechenitzkiy, H. Podlech, U. Rücker, M. Strobl, E. Vezhlev, J. Voigt, P. Zakalek

(percentage of completion)

# OUTLINE



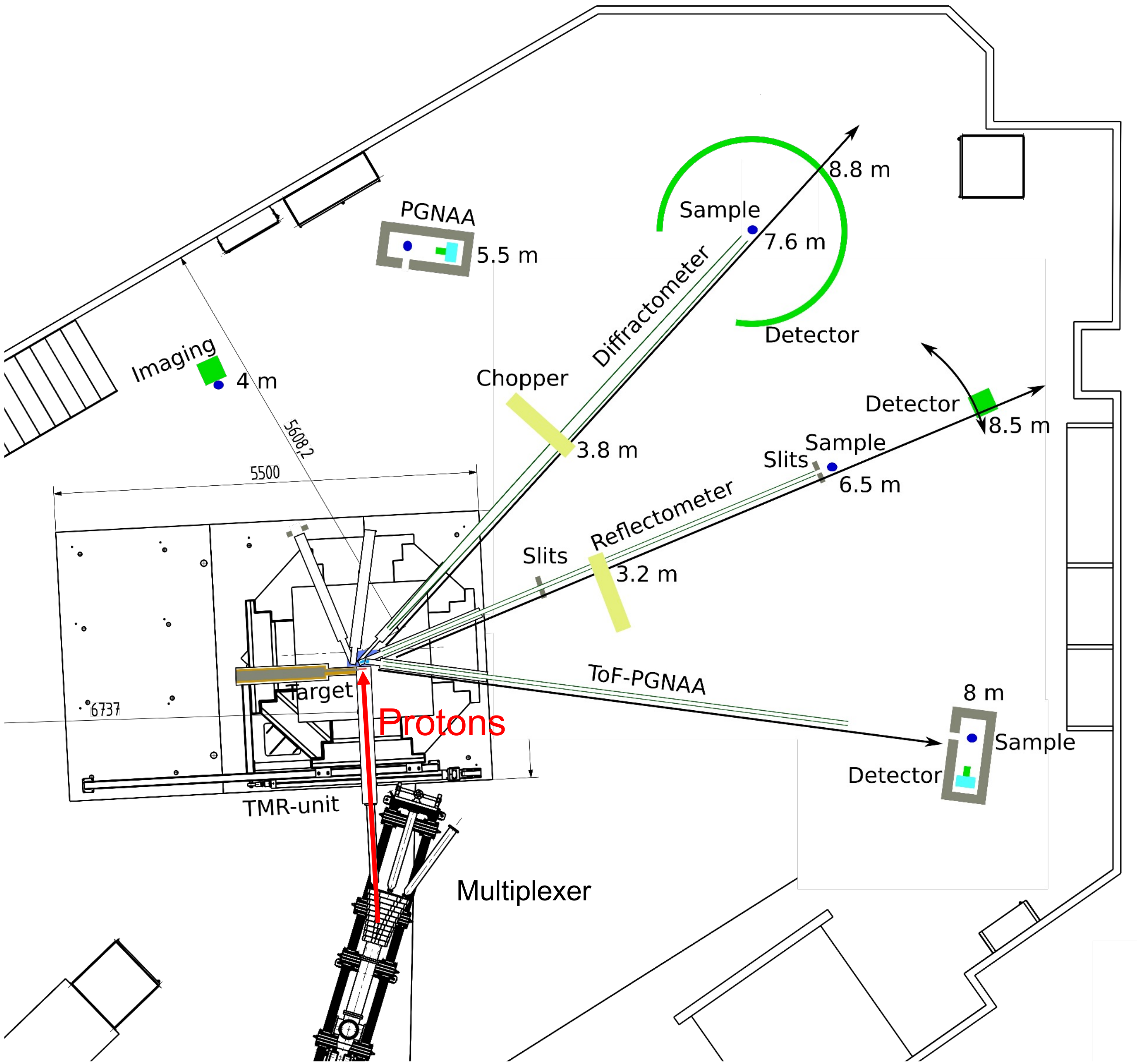


JÜLICH Forschungszentrum

# JULIC Neutron platform

| | Big Karl (test in Dec. 2022) | HBS |
|---|---|---|
| Particle type | Proton | Proton |
| Energy | 45 MeV | 70 MeV |
| Peak current | ~ 100 nA | 90 mA |
| Duty cycle | 4 % | 1.6 % |
| Average power | < 1 W | 100 kW |
| Neutron yield | $< 1 \cdot 10^{10}\ s^{-1}$ | $2 \cdot 10^{15}\ s^{-1}$ |

Big Karl experimental area allows performing basic neutron scattering experiments in time-of-flight mode

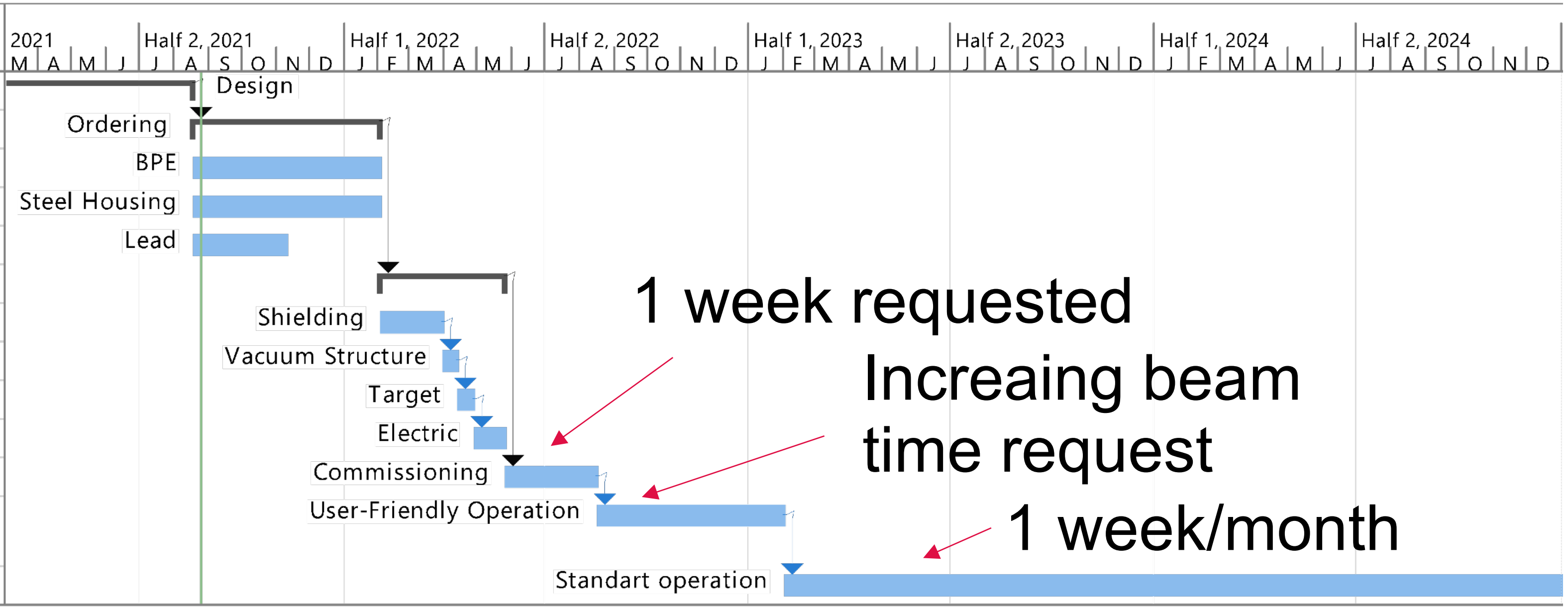





JÜLICH Forschungszentrum

# Timeline presented August 2021

| ID | | Task Mode | Task Name | Duration | Start | Finish |
|---|---|---|---|---|---|---|
| 1 | | | **Design** | **360 days** | **Wed 01/04/20** | **Tue 17/08/21** |
| 5 | | | **Ordering** | **120 days** | **Wed 18/08/21** | **Tue 01/02/22** |
| 6 | | | BPE | 6 mons | Wed 18/08/21 | Tue 01/02/22 |
| 7 | | | Steel Housing | 6 mons | Wed 18/08/21 | Tue 01/02/22 |
| 8 | | | Lead | 3 mons | Wed 18/08/21 | Tue 09/11/21 |
| 9 | | | **Setup** | **80 days** | **Wed 02/02/22** | **Tue 24/05/22** |
| 10 | | | Shielding | 2 mons | Wed 02/02/22 | Tue 29/03/22 |
| 11 | | | Vacuum Structur | 2 wks | Wed 30/03/22 | Tue 12/04/22 |
| 12 | | | Target | 2 wks | Wed 13/04/22 | Tue 26/04/22 |
| 13 | | | Electric | 1 mon | Wed 27/04/22 | Tue 24/05/22 |
| 14 | | | Commissioning | 3 mons | Wed 25/05/22 | Tue 16/08/22 |
| 15 | | | User-Friendly Operation | 6 mons | Wed 17/08/22 | Tue 31/01/23 |
| 16 | | | Standart operation | 500 days | Wed 01/02/23 | Tue 31/12/24 |

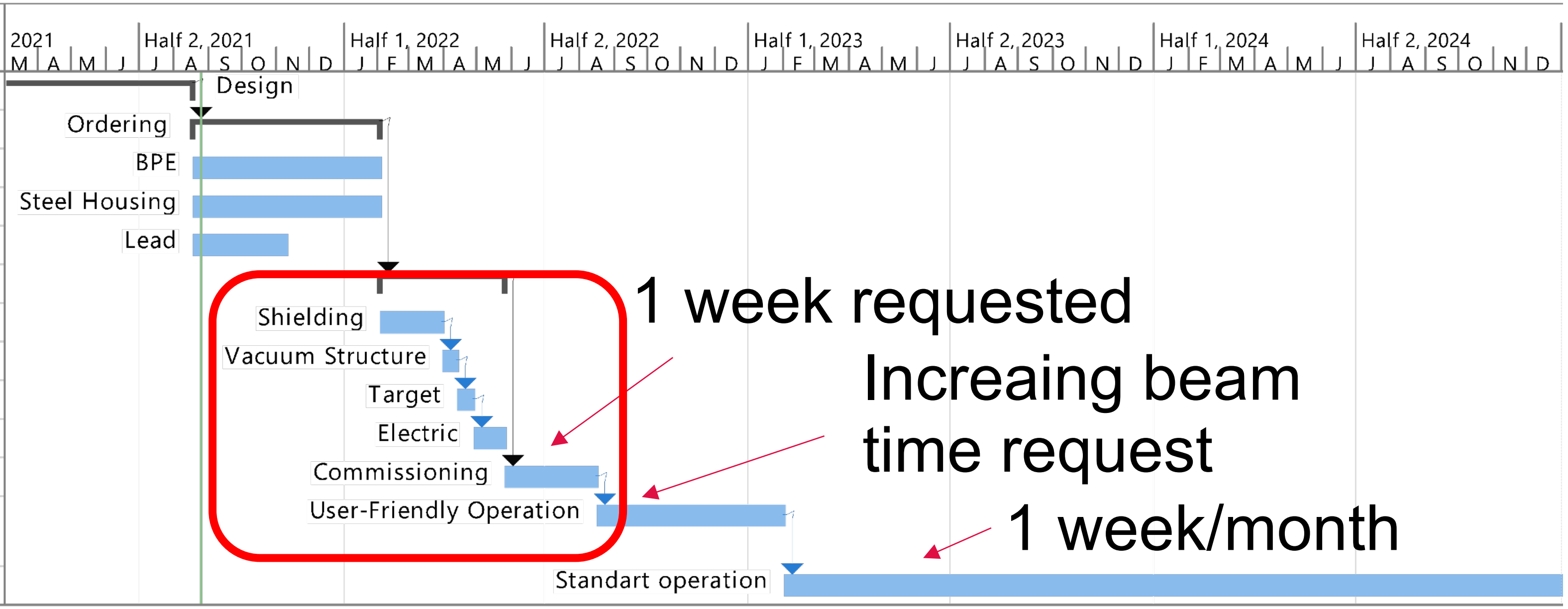





JÜLICH Forschungszentrum

# Timeline presented August 2021

| ID | | Task Mode | Task Name | Duration | Start | Finish |
|---|---|---|---|---|---|---|
| 1 | | | **Design** | **360 days** | **Wed 01/04/20** | **Tue 17/08/21** |
| 5 | | | **Ordering** | **120 days** | **Wed 18/08/21** | **Tue 01/02/22** |
| 6 | | | BPE | 6 mons | Wed 18/08/21 | Tue 01/02/22 |
| 7 | | | Steel Housing | 6 mons | Wed 18/08/21 | Tue 01/02/22 |
| 8 | | | Lead | 3 mons | Wed 18/08/21 | Tue 09/11/21 |
| 9 | | | **Setup** | **80 days** | **Wed 02/02/22** | **Tue 24/05/22** |
| 10 | | | Shielding | 2 mons | Wed 02/02/22 | Tue 29/03/22 |
| 11 | | | Vacuum Structur | 2 wks | Wed 30/03/22 | Tue 12/04/22 |
| 12 | | | Target | 2 wks | Wed 13/04/22 | Tue 26/04/22 |
| 13 | | | Electric | 1 mon | Wed 27/04/22 | Tue 24/05/22 |
| 14 | | | Commissioning | 3 mons | Wed 25/05/22 | Tue 16/08/22 |
| 15 | | | User-Friendly Operation | 6 mons | Wed 17/08/22 | Tue 31/01/23 |
| 16 | | | Standart operation | 500 days | Wed 01/02/23 | Tue 31/12/24 |




Delayed by 6 months due to delivery problems


JÜLICH Forschungszentrum

# ✓ TEST-FACILITY AT FZJ COMMISSIONED

## First beam on target on Dec. 12, 2022, with 3 beamlines in operation

### proton beamline from cyclotron

- 45 MeV pulsed protons, only nano Ampere current

### target-moderator-reflector (TMR) unit

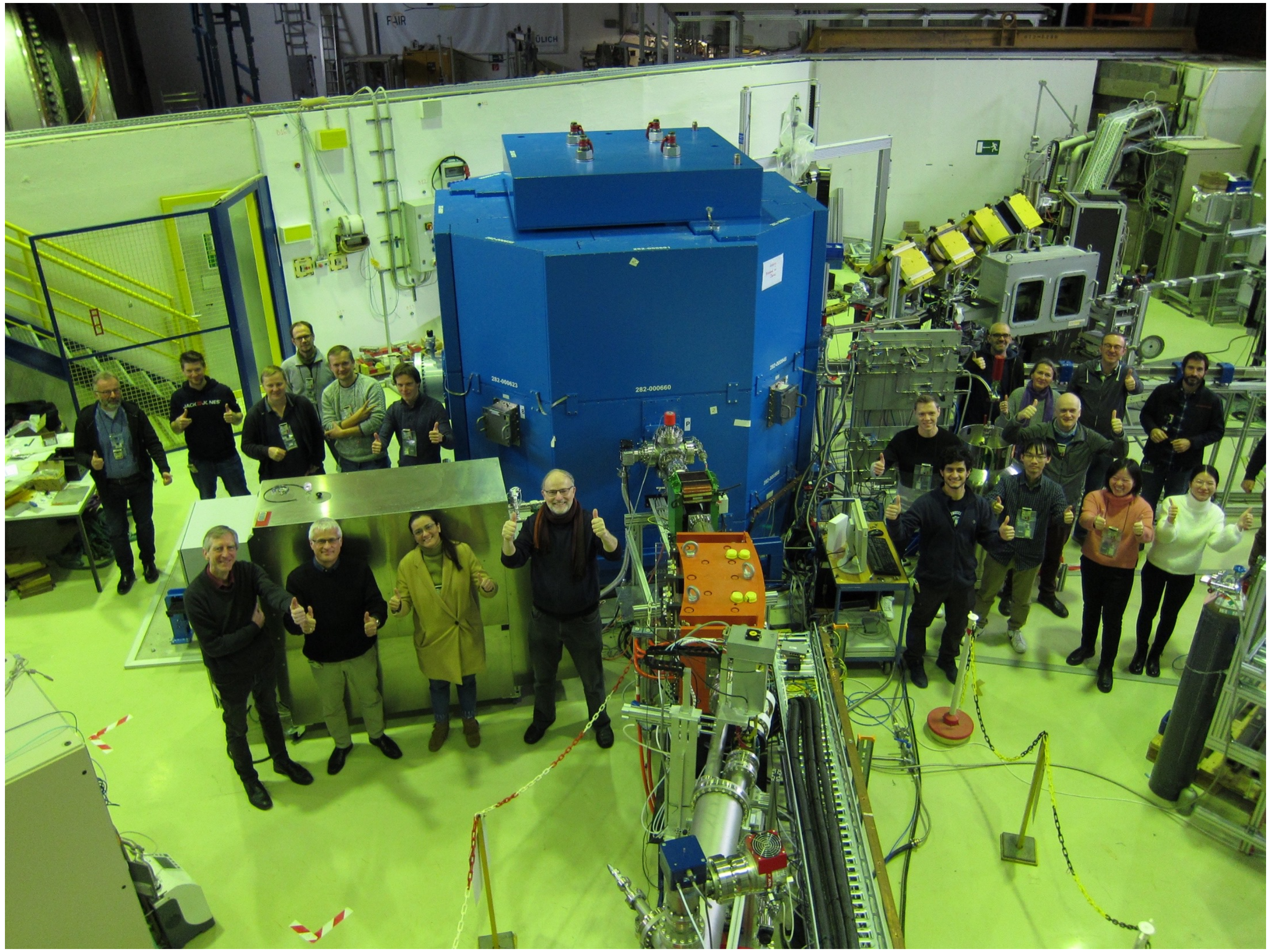
- HBS Ta-target, PE-moderator, Pb-reflector

### cold methane moderator

- spectrum measured at various temperatures

### three beamlines in operation

- time-of-flight diffractometer:
  neutron energy spectrum, first diffractogram
- HERMES reflectometer provided by LLB:
  total reflection edge of supermirror
- detector test station:
  SONDE detector for ESS tested



# OUTLINE

- Motivation: Changing European Neutron Landscape
- The HBS Project: the HiCANS Technology Leader
- JULIC Neutron Platform: a testbed for HBS
- **Proposed beamtimes**
- Summary

# JULIC NEUTRON PLATTFORM:  GOALS

**verify MCNP simulations**

- neutron yield for real configuration

**optimize target-moderator coupling**

- adjustable inner part for thermal moderator

**cryogenic finger moderators**

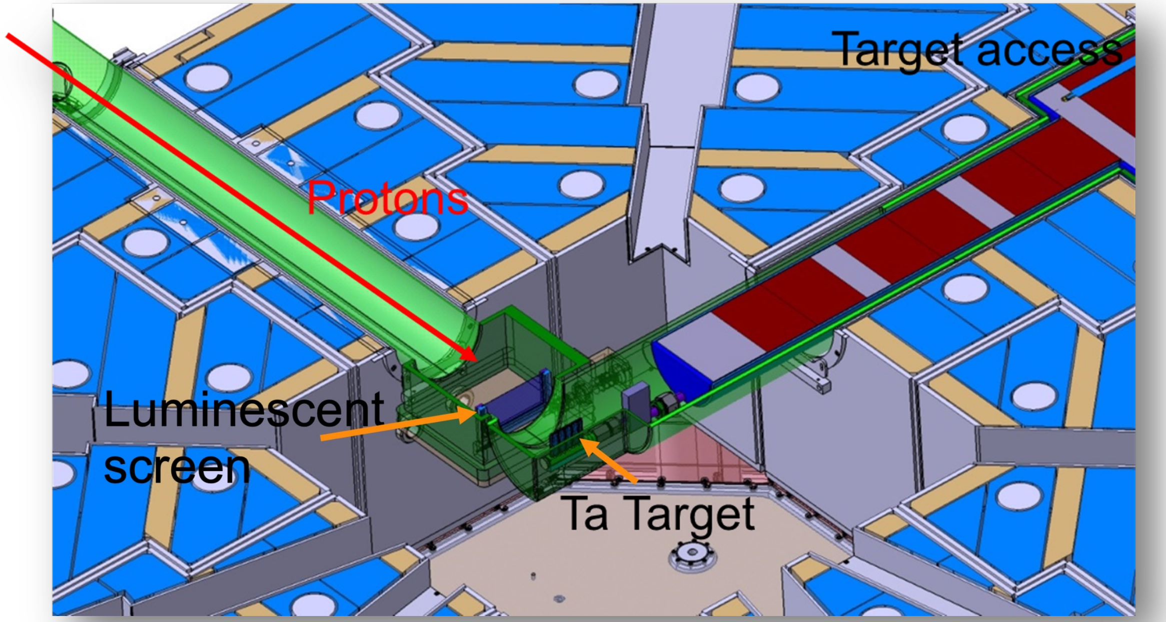
- spectra of various moderators:
  first of their kind 1 d moderators
  (para-hydrogen, mesitylene, methane, …)

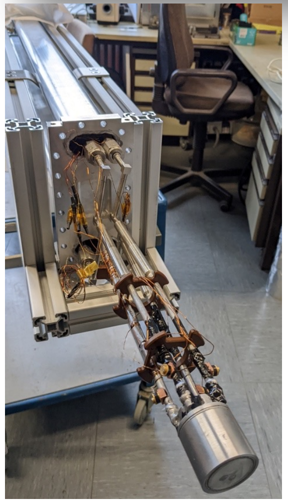
**target handling**

- automized exchange of activated target

**neutron analytics method development**

- ToF – PGAA (neutron activation analysis)



low dimensional
cryogenic moderators,
exchange plug

# Further Plans: six times one week of beamtime requested

**Realization of a fully operational target station**

- Finish commissioning: target, handling tool
- Operate target at designed power

**Reflectometry measurements (courtesy of LLB)**

- Experiment with higher power and cold moderator
- Prove feasibility of HBS concept

**Measurement of a para-hydrogen moderator**

- Operation  and characterization of low dimensional moderator in realistic target station

**Neutron analytics and imaging**

- Setup ToF-PGNAA option on diffractometer
- Perform prove of concept experiment

**Optimization of thermal and cold moderators with additional cold moderator materials**

- Improve performance with e.g. cadmium slits
- Investigate other materials e.g. mixture of mesitylene and m-xylene

**Additional tests and experiments**

- Open beam time for questions arising during other experiments

→ Successful beam on target but many open questions remaining

# Experimental preparation and readiness

### Necessary work for full potential

- Shield proton beam line to reduce background and increase beam current to 10 µA
- Replace old target with new target design
- Fix required liquid $H_2$ moderator for HERMES reflectometer
- Improve beam current measurements

### Possible measurements in 1. half of 2023

- Spectra measurements of moderator vessel filled with liquified gases e.g. methane, ethane, …
- Further detector tests

### Full operation 2. half of 2023

- All experiments possible and ready

→ **Reduced readiness within 3 months**

→ **Request 1 week every month in 2. half of 2023**

# OUTLINE

# Summary

- The JULIC Neutron platform at the COSY facility allows relevant experiments regarding TMR
- Critical components like target, extraction channels, moderators, target handling can be tested
- Neutron yield is sufficient high to perform basic experiments. Estimation of instrument performance is planned
- Successful first beam on target performed on 12.12.2022 but many open questions are remaining

# Requirements / Requests

- Installation of shielding around accelerator and upgrade of beam current to 10 μA
- 6 weeks of beamtime for 2023 in second half
- 1 week every month for experiments at TMR and operation of neutron scattering instruments

essential testbed for an entirely new type of neutron facility, which can rejuvenate the European neutron eco-system

# HBS Team

J. Baggemann
Th. Brückel
J. Chen
T. Claudio Weber
T. Cronert (†)
Q. Ding
M. El-Barbari
T. Gutberlet
J. Li
K. Lieutenant
Z. Ma
E. Mauerhofer
U. Rücker
N. Schmidt
A. Schwab
J. Voigt
P. Zakalek

*- Core group: design, verification, instrumentation*

**ZEA-1:**
Y. Bessler
R. Hanslik
R. Achten
F. Löchte
M. Strothmann

*- Engineering*

**IKP-4:**
O. Felden
R. Gebel
A. Lehrach
M. Rimmler
R. Similon

*- Nuclear physics*

**INM-5:**
B. Neumaier

*- Radio isotopes*

S. Böhm
R. Nabbi

*- Nuclear simul.*

C. Lange
Ch.Haberstroh
S. Eisenhut

*- AKR-2, liquid $H_2$*

H. Podlech
O. Meusel

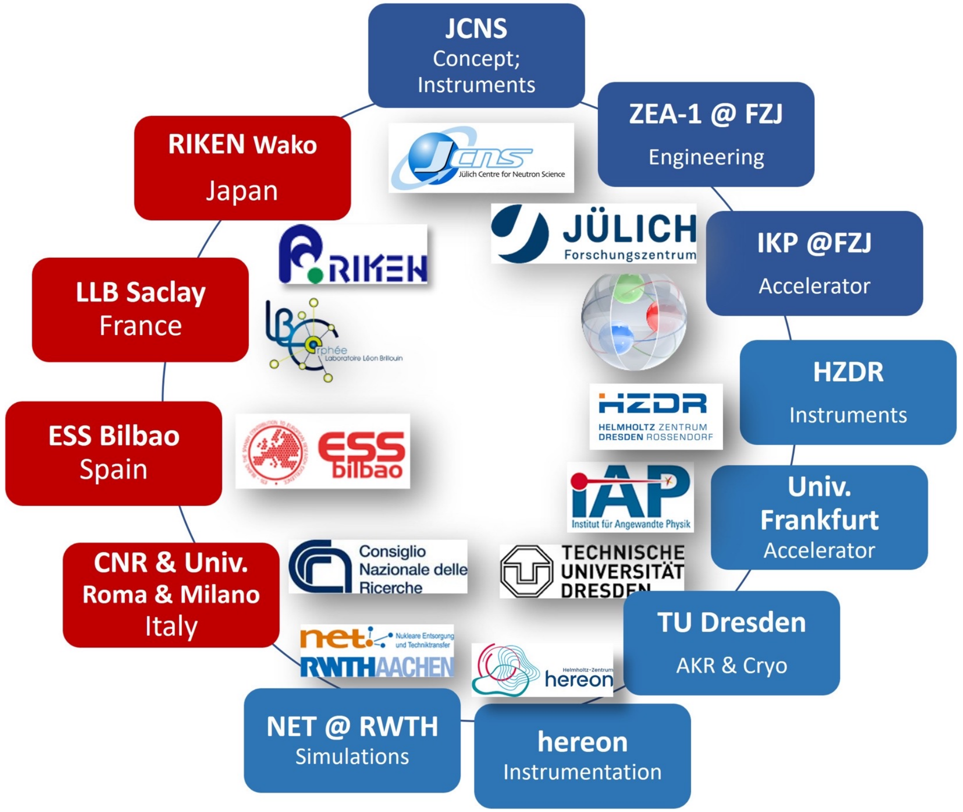
*- Accelerator*

/ HIM
W. Barth

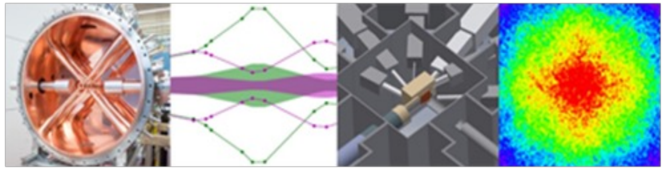
*- Accelerator*

J. Fenske

*- Instrumentation*




## HBS Innovationpool Project



FB Matter: MML, MT

Federal Ministry of Education and Research

ELENA
European Low Energy accelerator-based Neutron facilities Association
www.elena-neutron.eu

JÜLICH Forschungszentrum