HIGH BRILLIANCE NEUTRON SOURCE

Status of the HBS Project

19 SEPTEMBER 2018 I JOHANNES BAGGEMANN

Jülich Centre for Neutron Science

HIGH BRILLIANCE SOURCE

JÜLICH Forschungszentrum

OUTLINE

- Motivation: Why do we need a HBS (High Brilliance Neutron Source) ?
- What is the HBS?
- Status of the HBS Development:
    - accelerator
    - target
    - shielding
    - moderator
    - instrumentation

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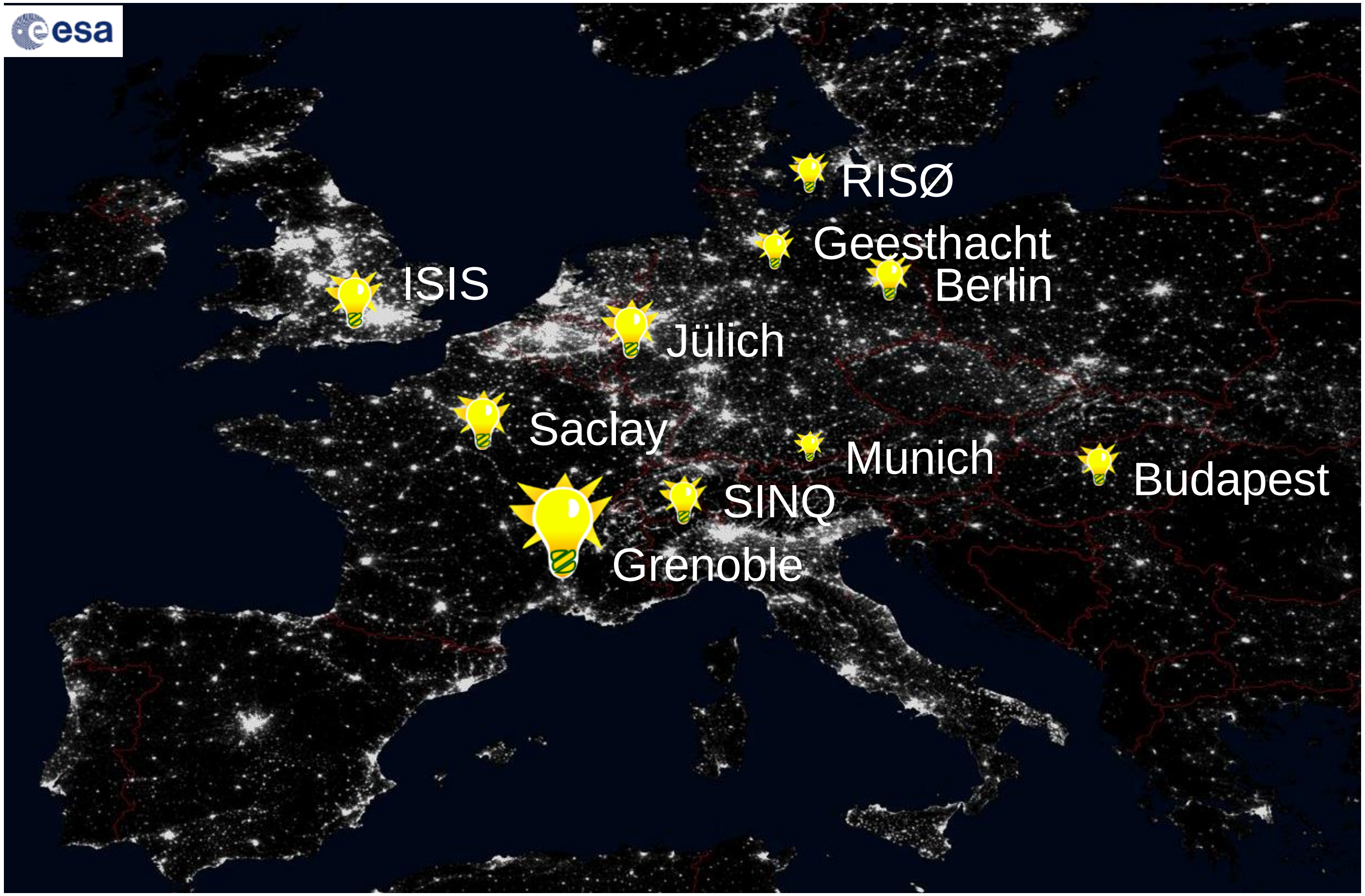
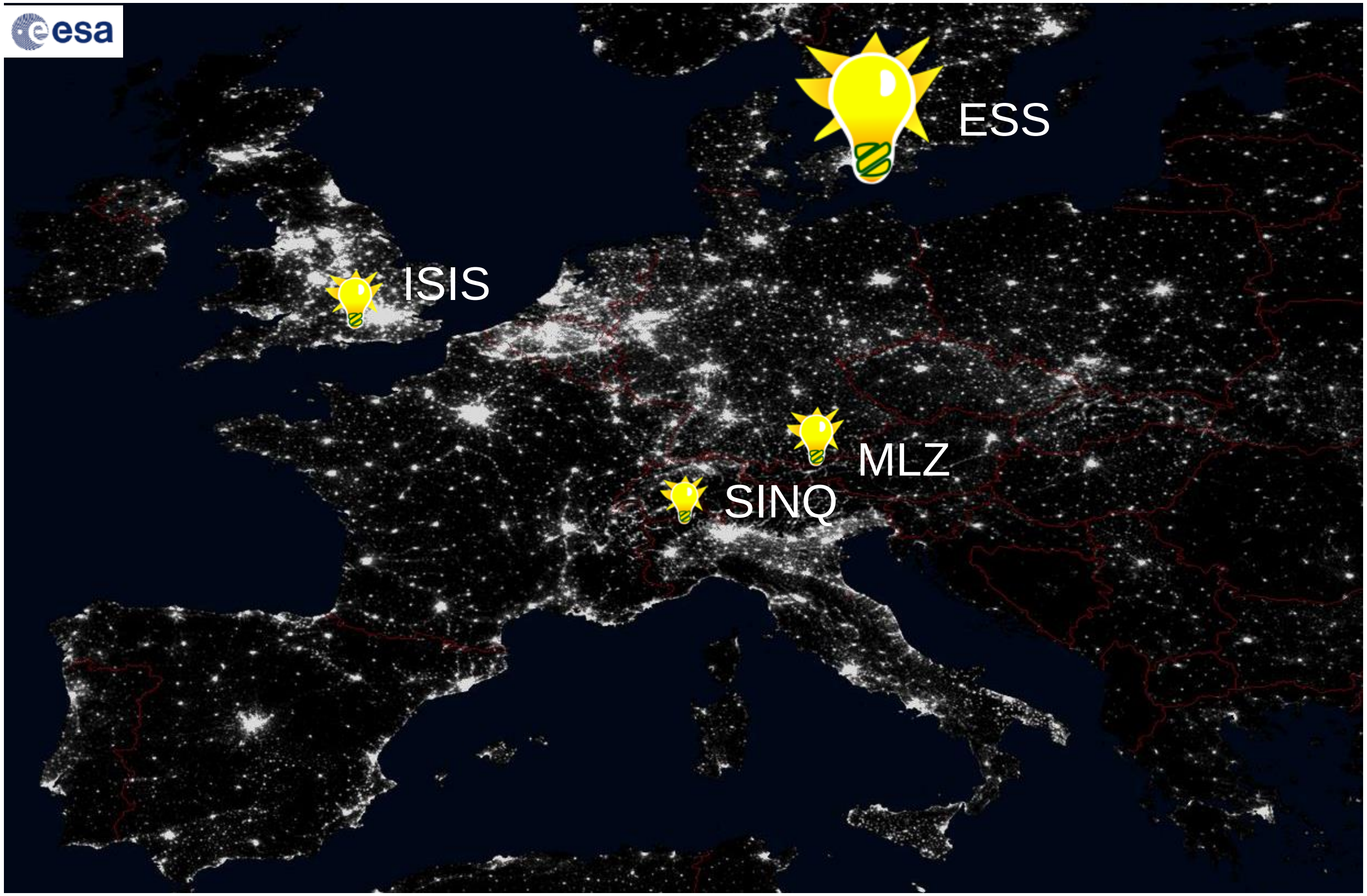
LARGER NEUTRON CENTRES

before 2000



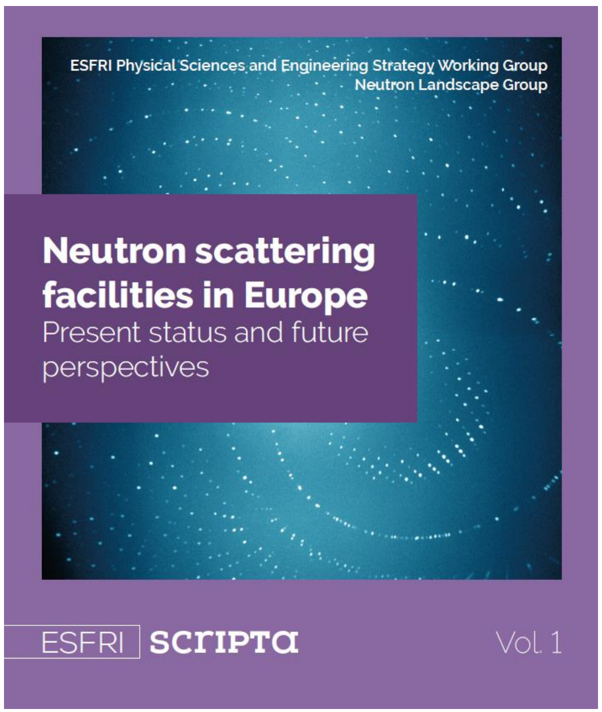
POSSILBLE NEUTRON SCENARIO

after 2030



EUROPEAN NEUTRON LANDSCAPE

Status and Perspectives



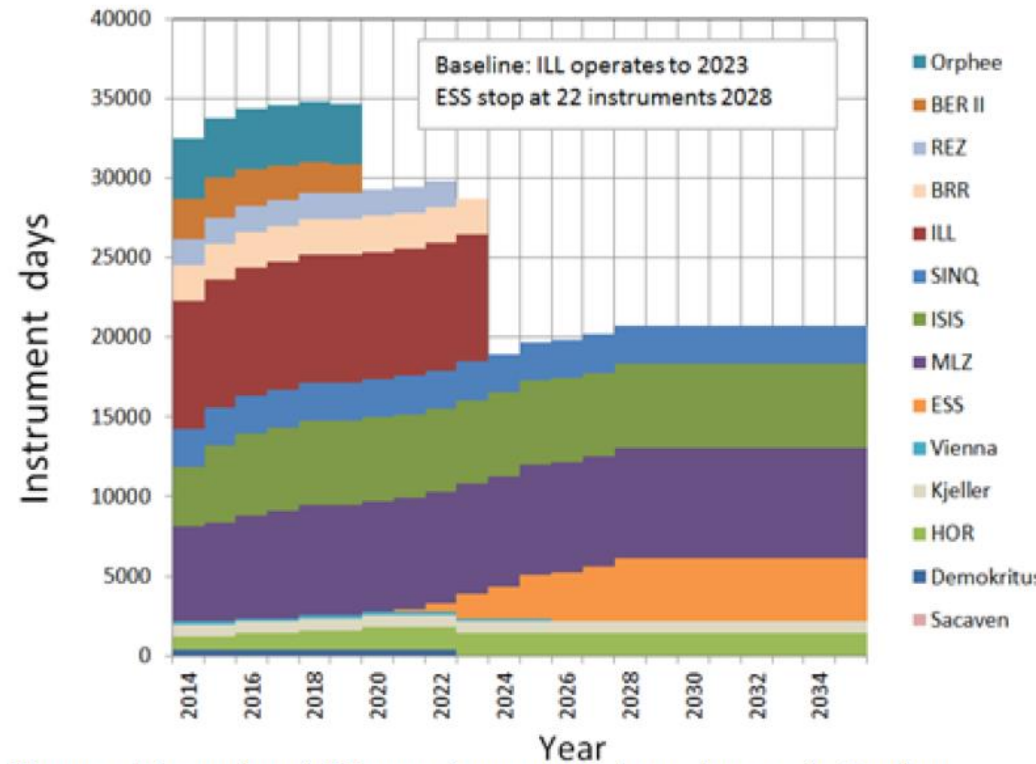


Figure 8. *The predicted delivery of instrument beam days in the Baseline Scenario*

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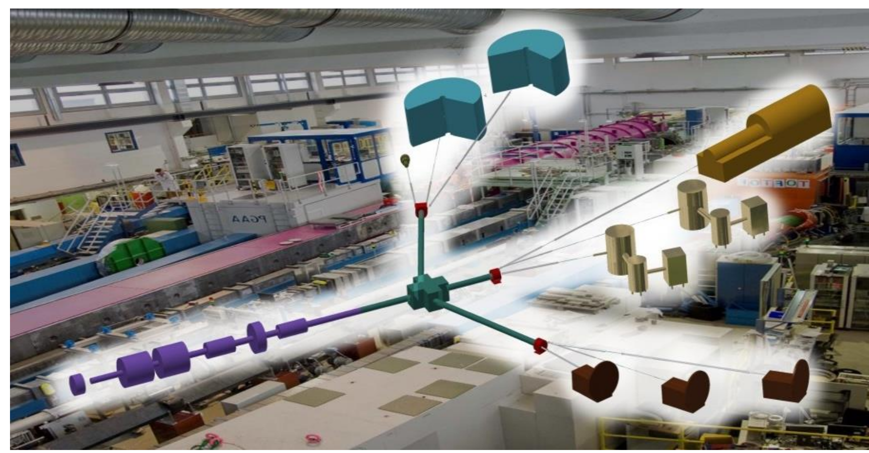
HIGH BRILLIANCE NEUTRON SOURCE

Bases on nuclear reactions such as p,n - reaction

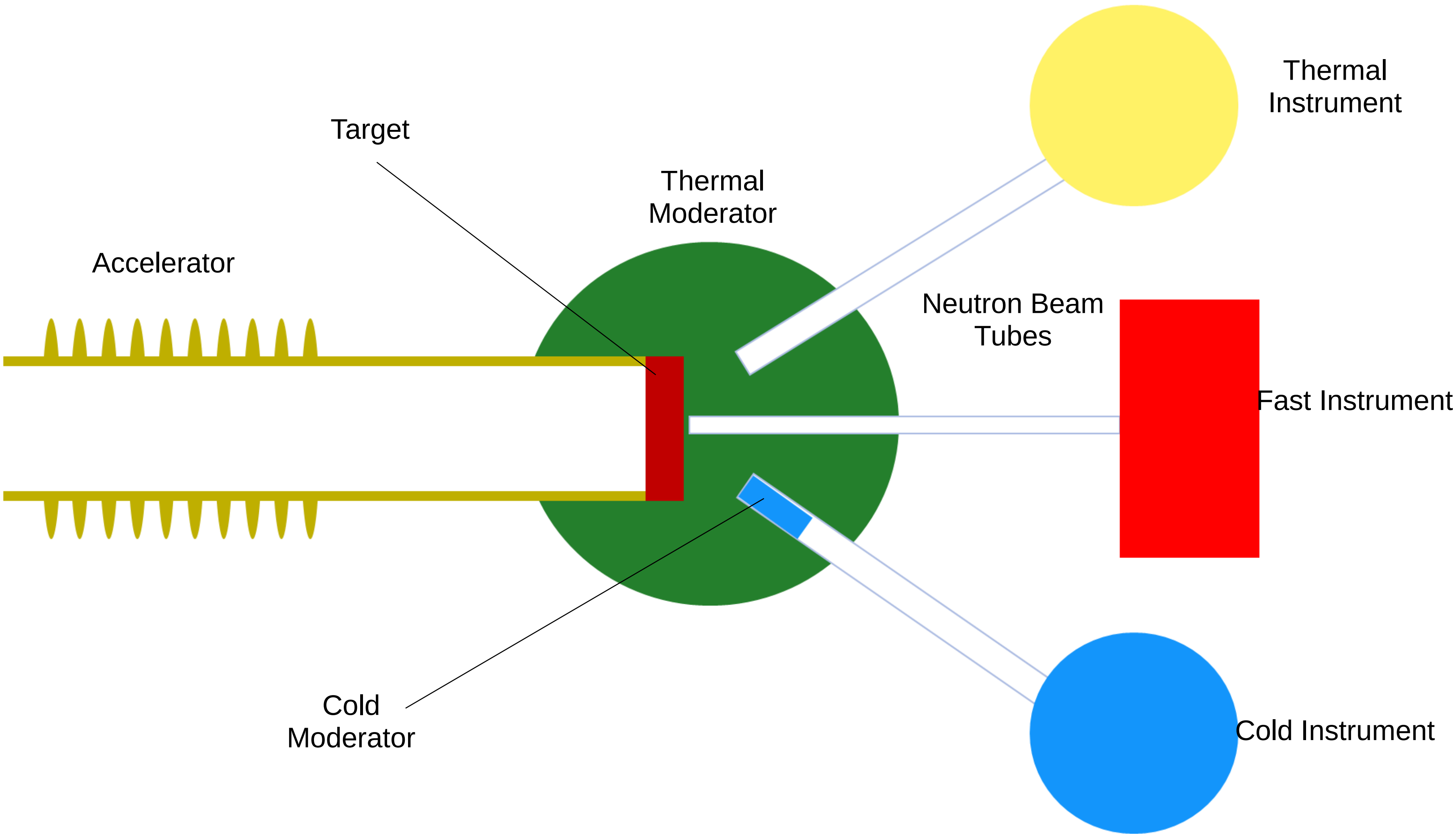
- accelerator driven pulsed neutron source
- primary Ion Energy below spallation reaction threshold
- optimized for neutron scattering on small samples
- scalable: low- or medium flux neutron laboratories (except target design)
- reasonable costs (~10 to ~300 MEUR)

holistic optimization of

- **Instrumentation**
- **Moderator**
- **Target**
- **Accelerator**



HBS – BASIC PRINCIPLE



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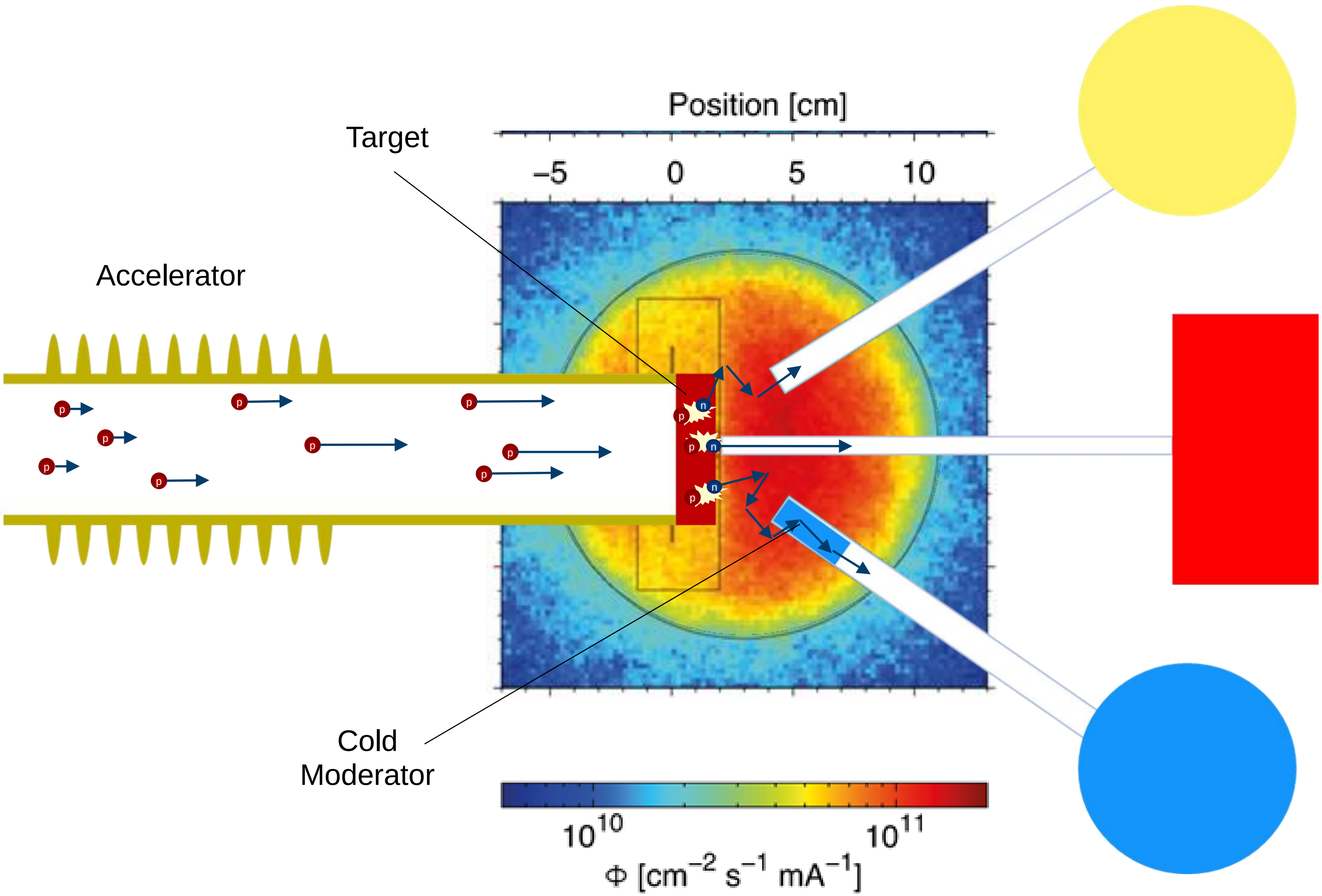
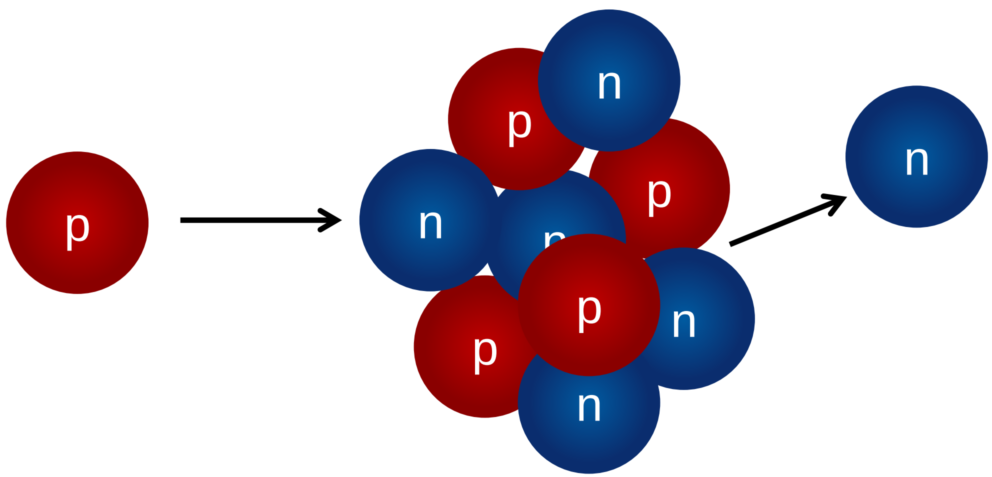


BASIC PRINCIPLE: NUCLEAR REACTION

nuclear reactions e.g.: (p, n) or (p, 2n) or (p, n + a)

$$proton \quad + \quad {}^{9}_{4}Be \rightarrow neutron\ (+\ {}^{9}_{5}B)$$



EUROPEAN NEUTRON LANDSCAPE

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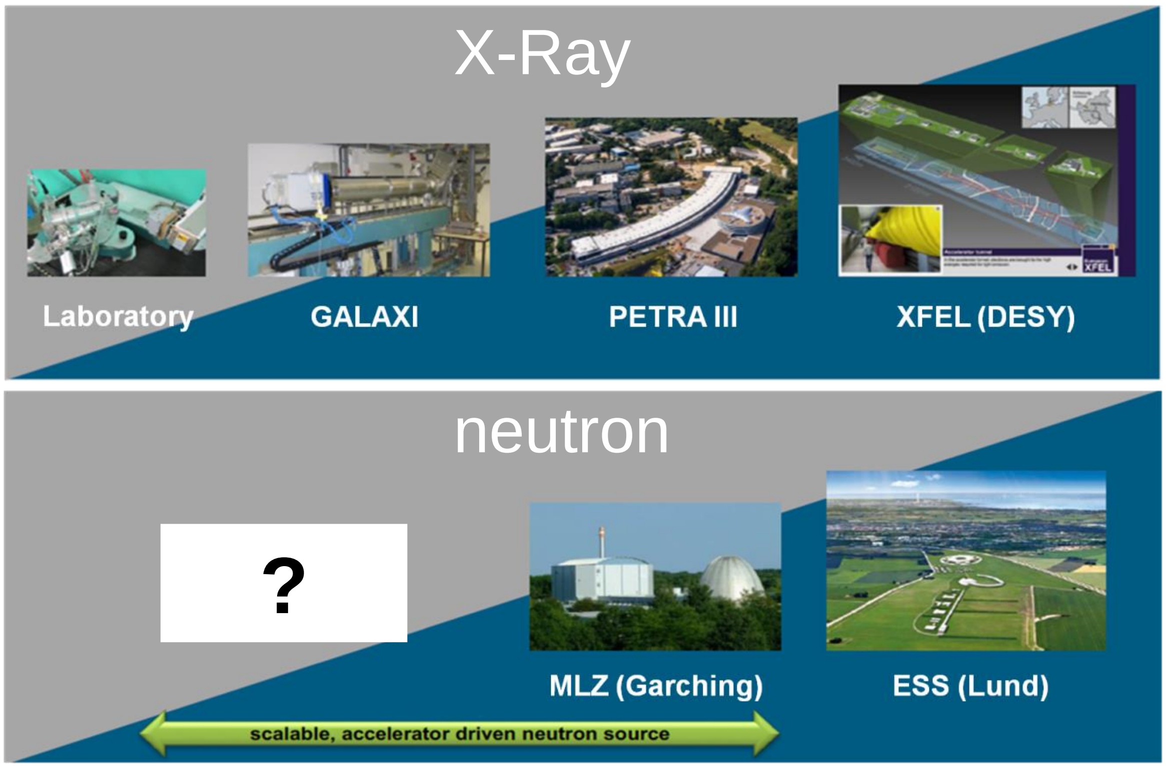


HBS project:

scalable accelerator

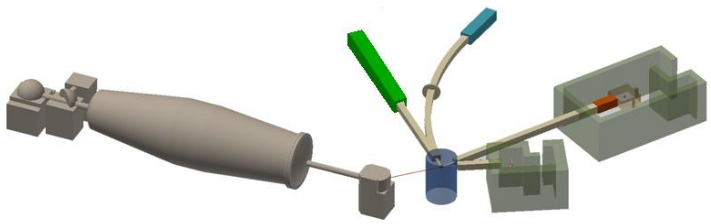
driven neutron source

HIGH BRILLIANCE NEUTRON SOURCE PROJECT

Realisations

Laboratory facility: NOVA ERA

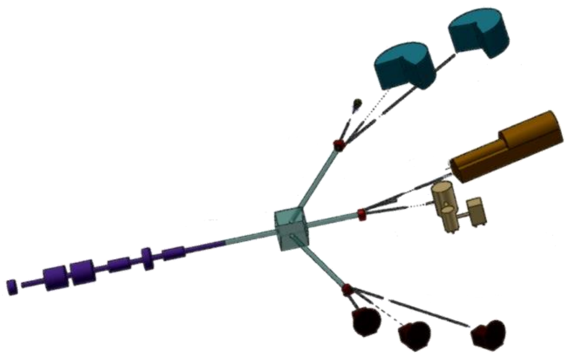
- small accelerator (~10 MeV)
- single target station
- basic instruments for research, education and training
- 0,4 – 1 kW thermal power



CDR available*

Large-scale facility: HBS

- linear accelerator (70 MeV)
- several target stations
- full suite of instruments with competitive performance
- 100 kW thermal power



CDR in progress

* http://www.fz-juelich.de/SharedDocs/Downloads/JCNS/JCNS-2/EN/Conceptual-Design.html

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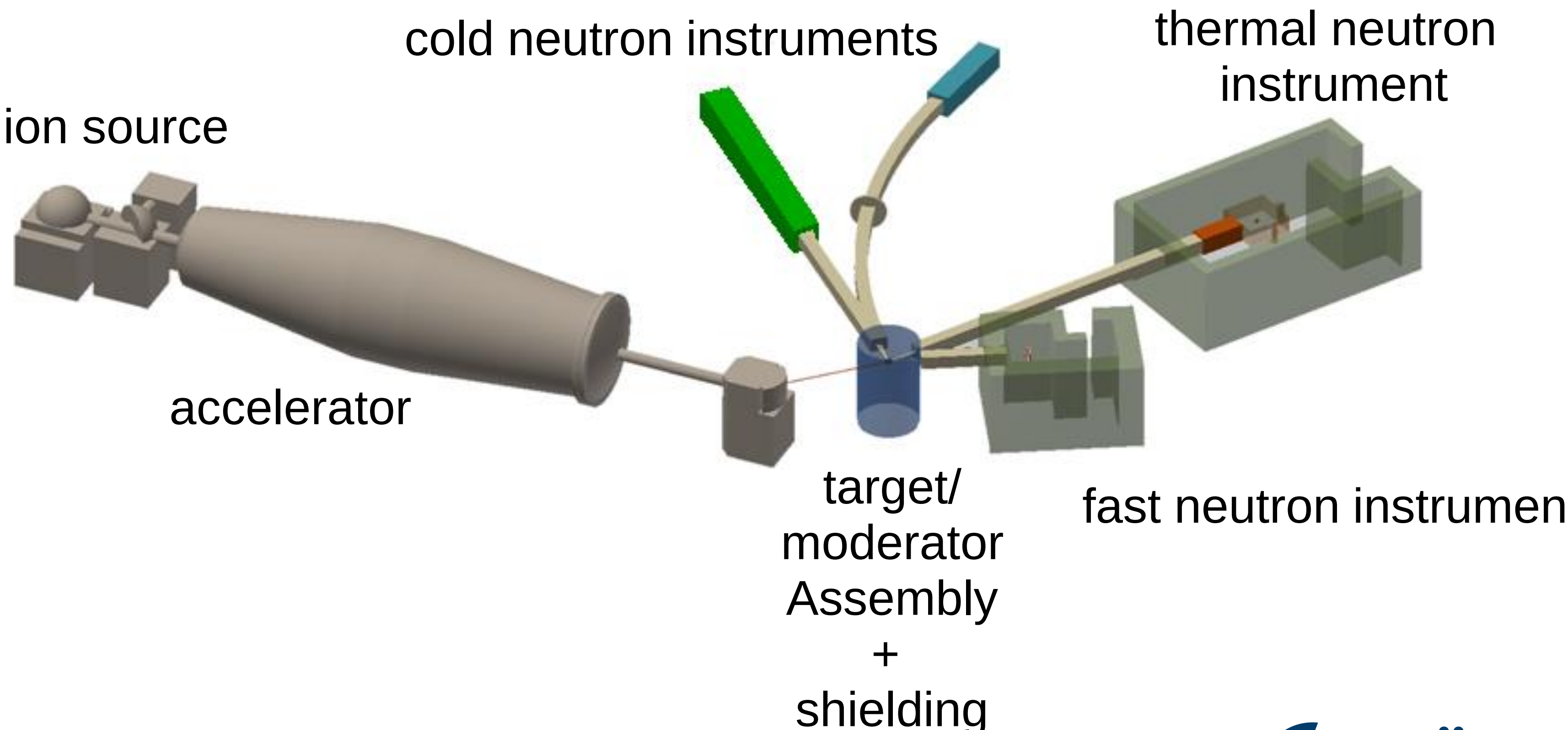
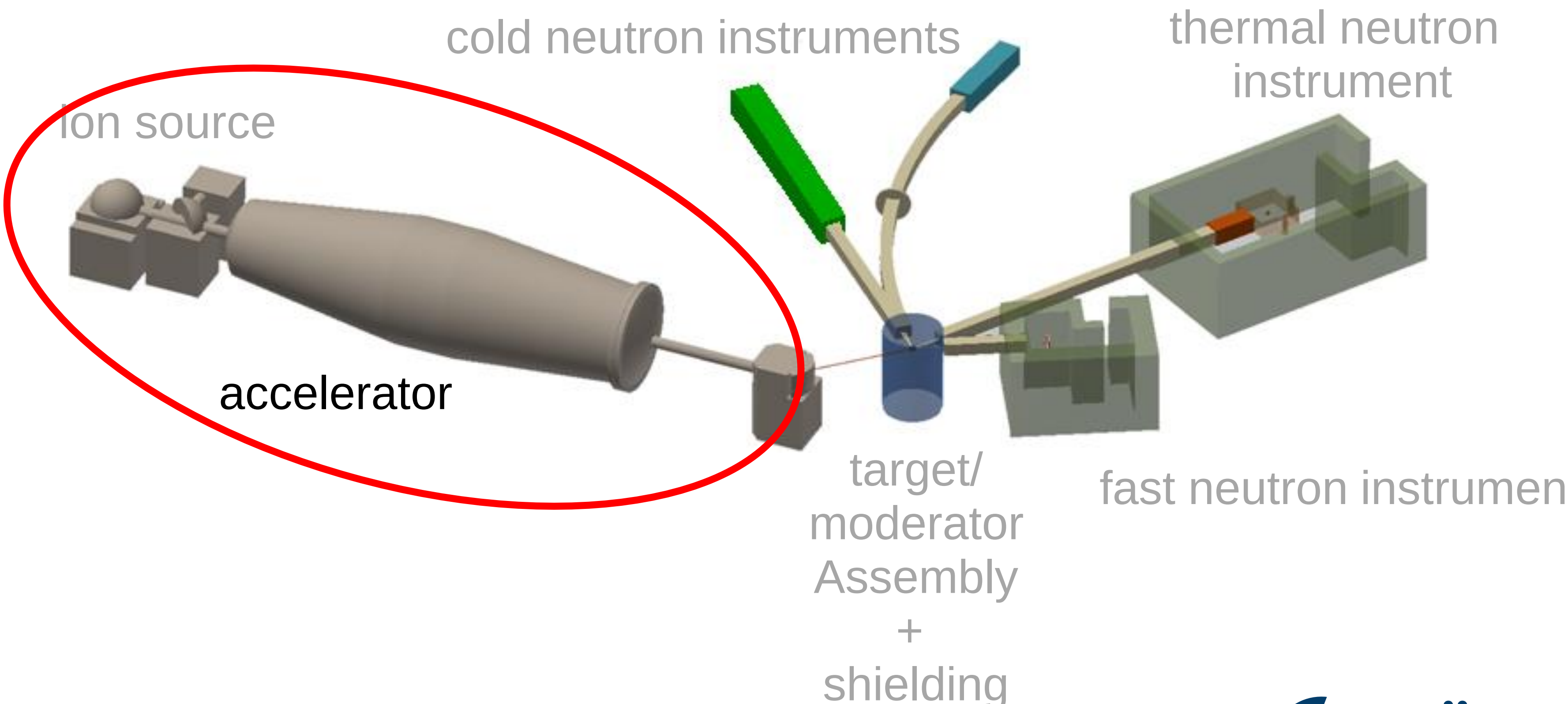
HBS – BASIC PRINCIPLE



HIGH BRILLIANCE NEUTRON SOURCE

Accelerator



ACCELERATOR

Pulsed proton beam

Laboratory facility: NOVA ERA

commercial accelerator

such as tandetron accelerator

- 10 MeV protons
- 1 mA peak current
- 4 % duty cycle

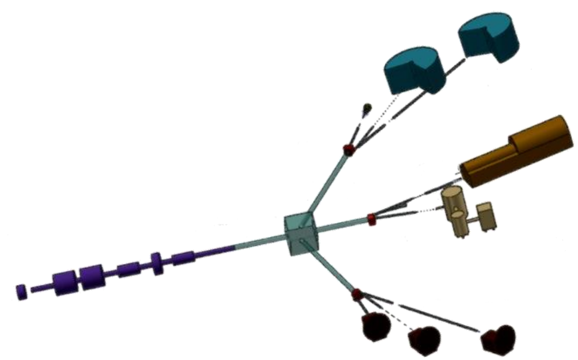
Source: highvoltage.com

Large-scale facility: HBS

new accelerator development necessary

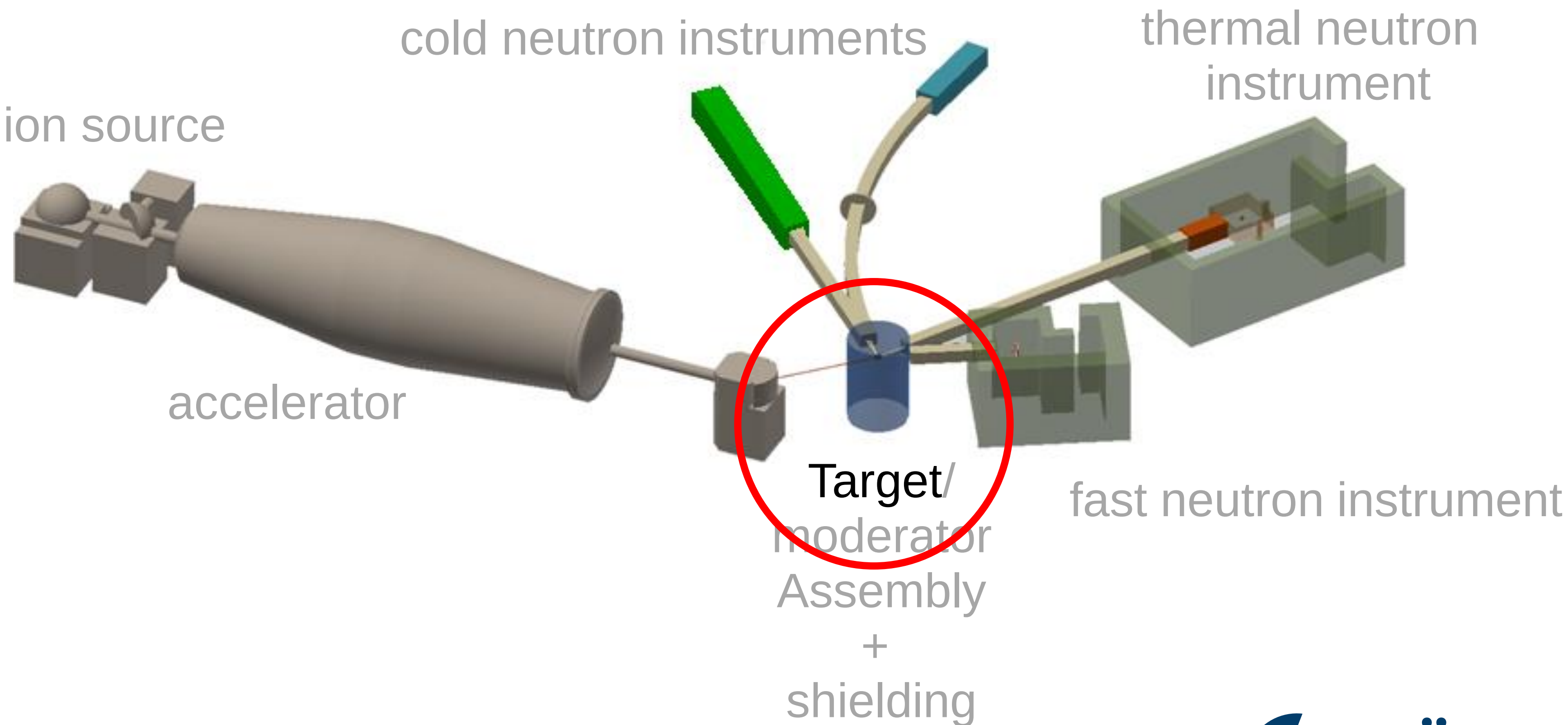
linear accelerator

- 70 MeV protons
- 100 mA peak current
- 2 - 4 % duty cycle



HIGH BRILLIANCE NEUTRON SOURCE

Target / moderator assembly



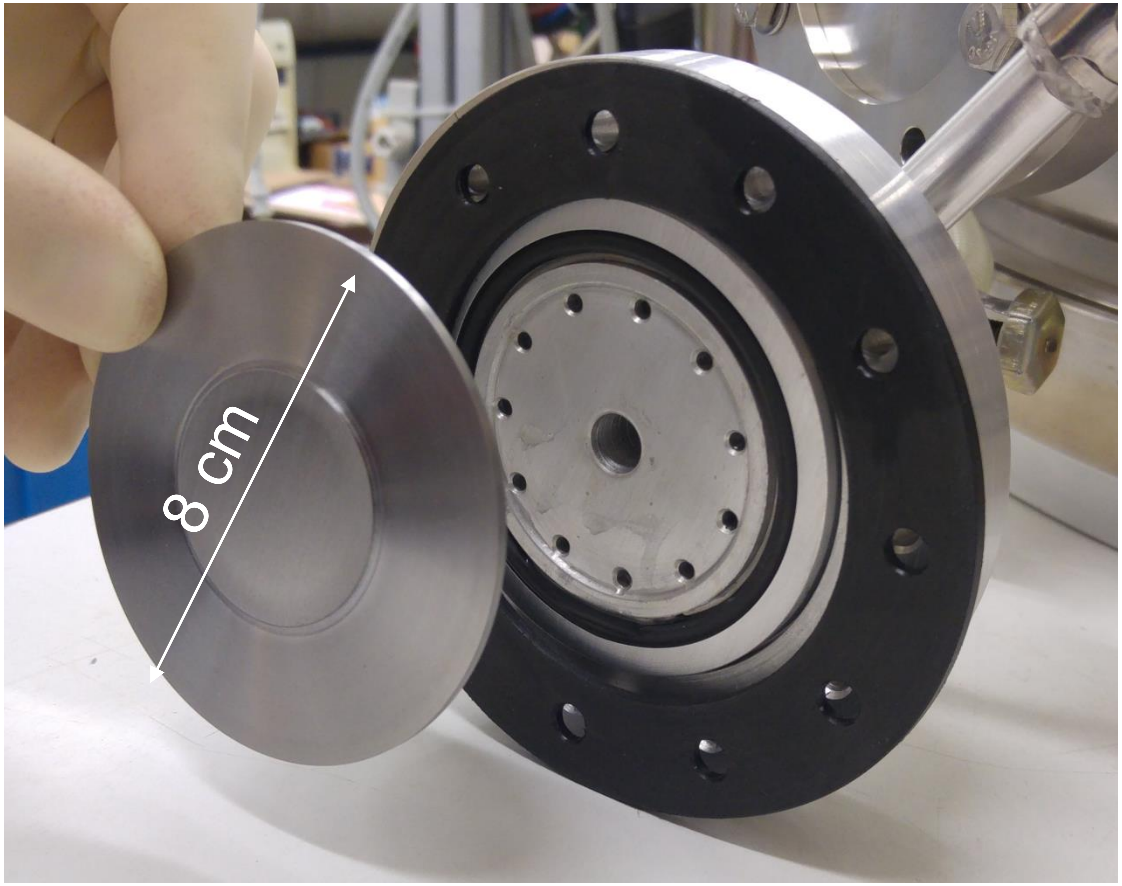
NOVA ERA TARGET

400 W thermal load

at 10 MeV proton energy

low atomic number z materials are preferable

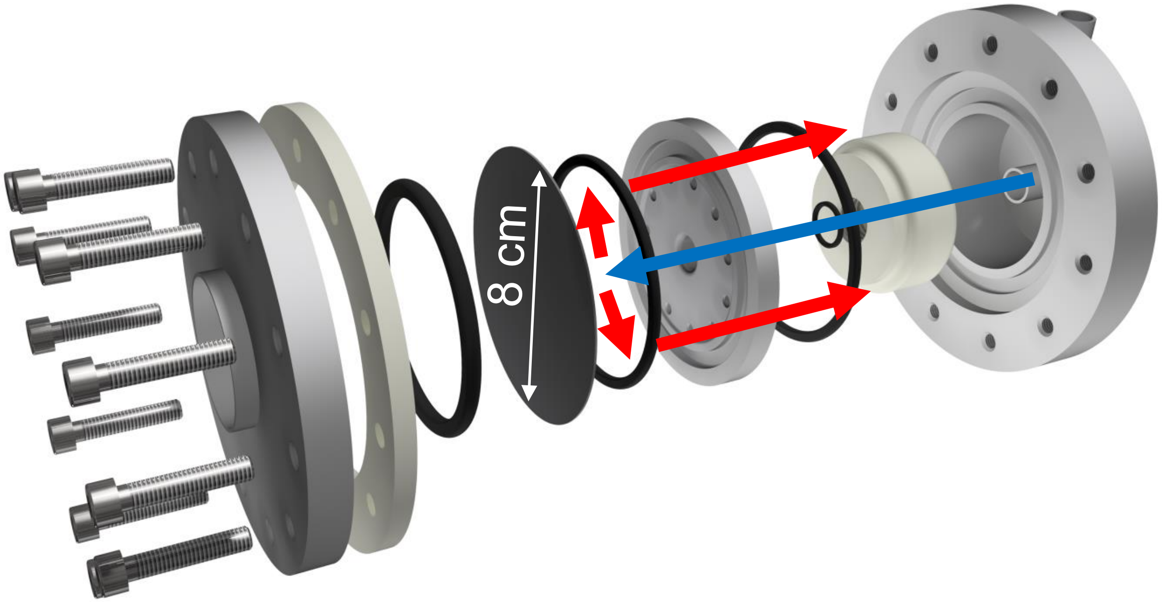
- Beryllium or vanadium
- diameter: 80 mm
- thickness: 0,7 mm
- thermal load: 400 W



NOVA ERA TARGET

Status: designed and build, tests will start soon

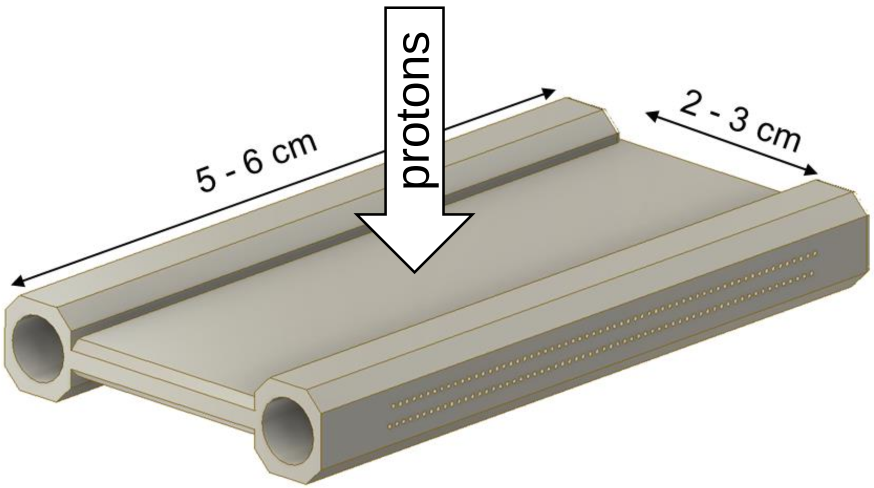
target test facility



target design

HBS TARGET

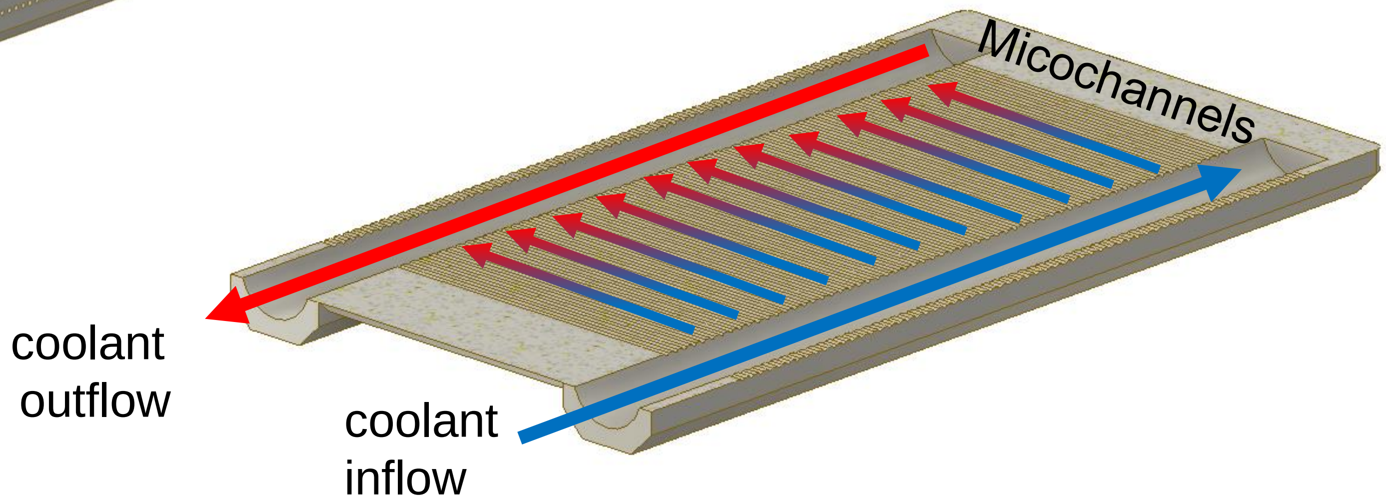
100 kW thermal load at approximately 100 cm²



high z materials preferable

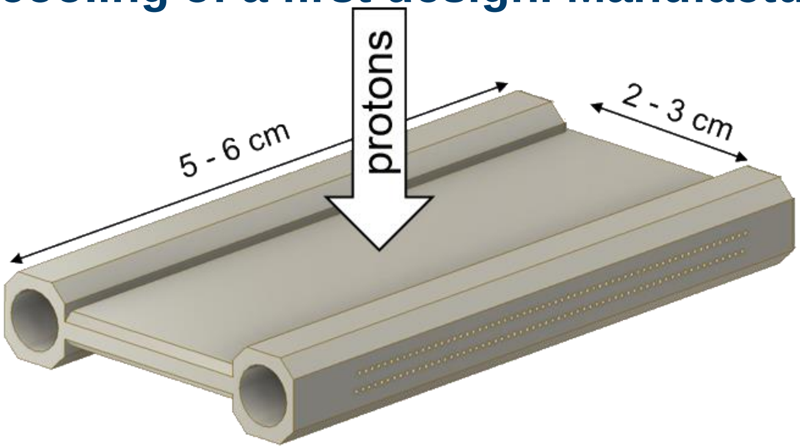
at 70 MeV proton energy

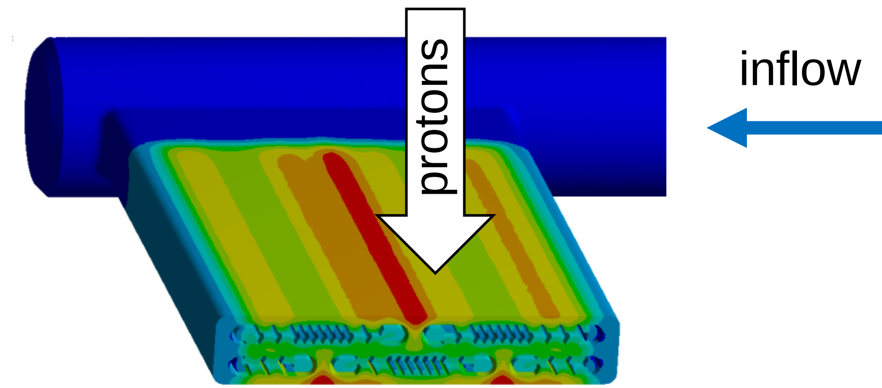
- tantalum
- diameter: 100 mm
- thickness: 5 mm



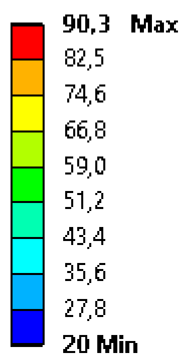
HBS TARGET

Status: CFD and mechanical simulations indicates sufficient stability and cooling of a first design. Manufacturing will start end of 2018

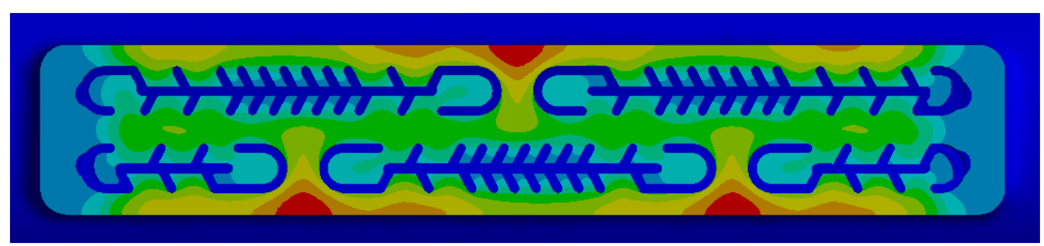




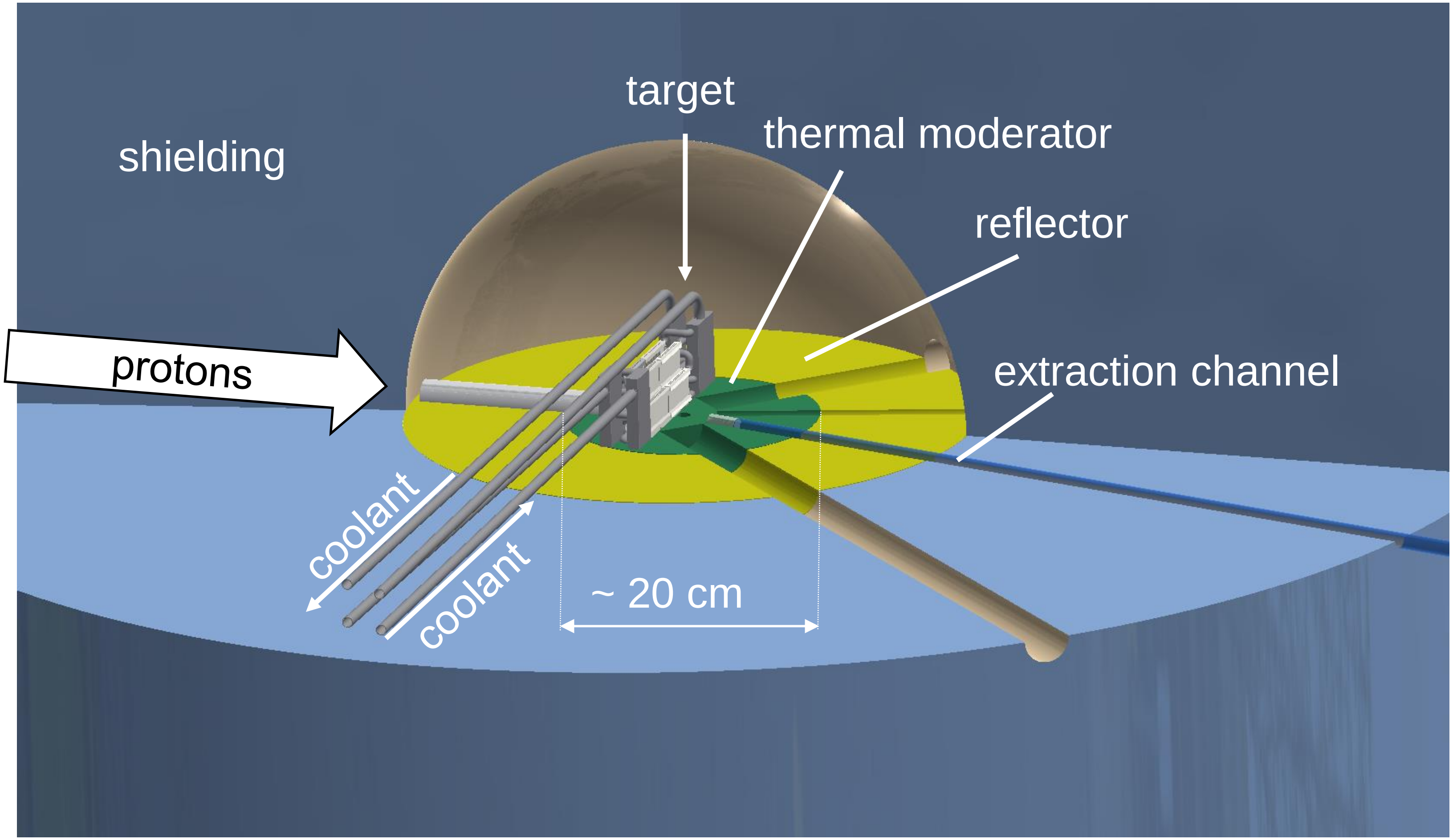
Temperature / °C



target cross section:

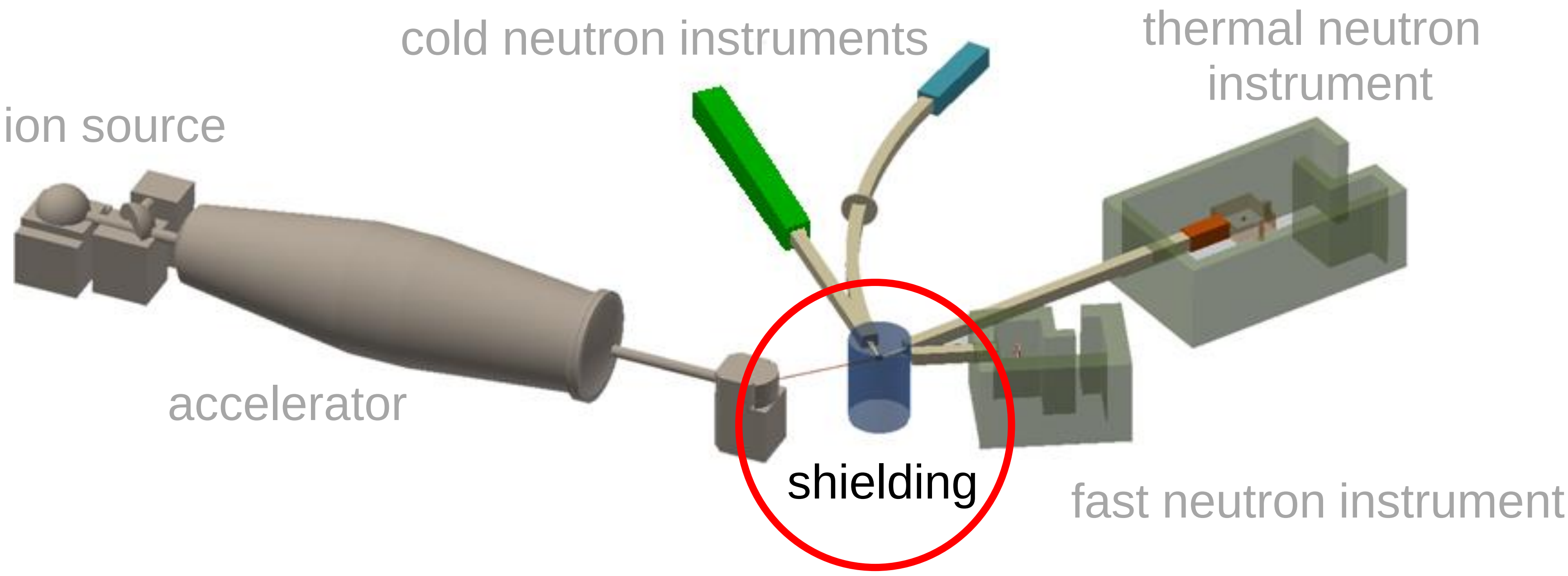


HBS – BASIC PRINCIPLE



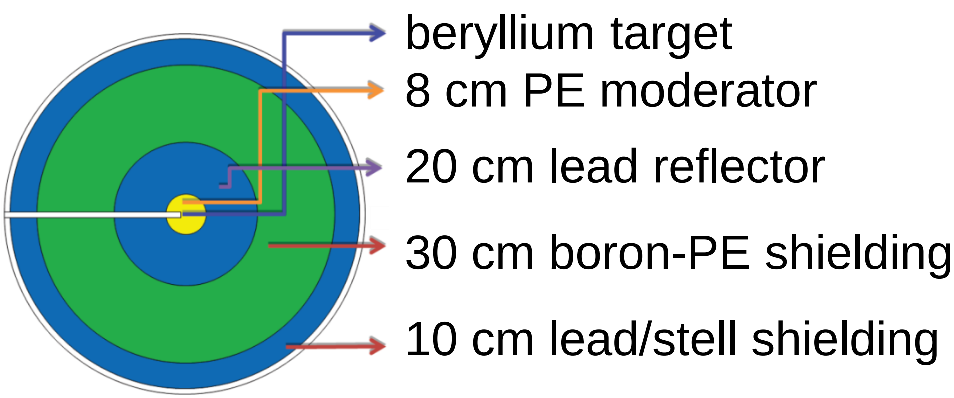
HIGH BRILLIANCE NEUTRON SOURCE

Target / moderator assembly

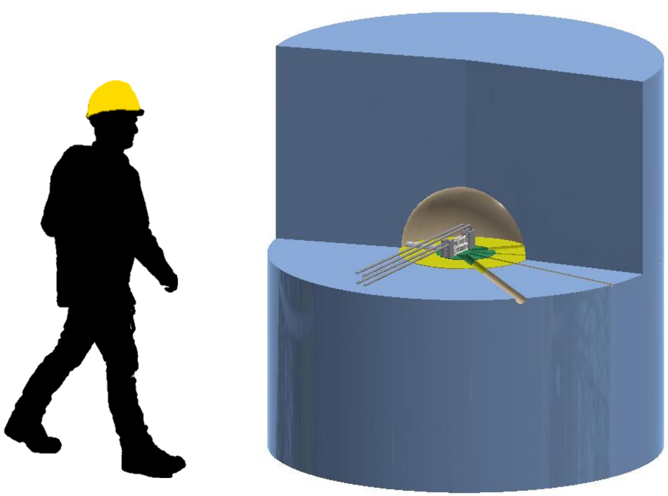


NOVA ERA SHIELDING

Very compact shielding design possible!



Thickness of borated PE (cm)	Neutron DR (mSv/a)	Gamma DR (mSv/a)
10	65	0.2
20	36	0.04
30	5	0.02
40	0.8	0.004
50	0.3	0.004
[illegible]	[illegible]	02
[illegible]	[illegible]	01
[illegible]	[illegible]	004

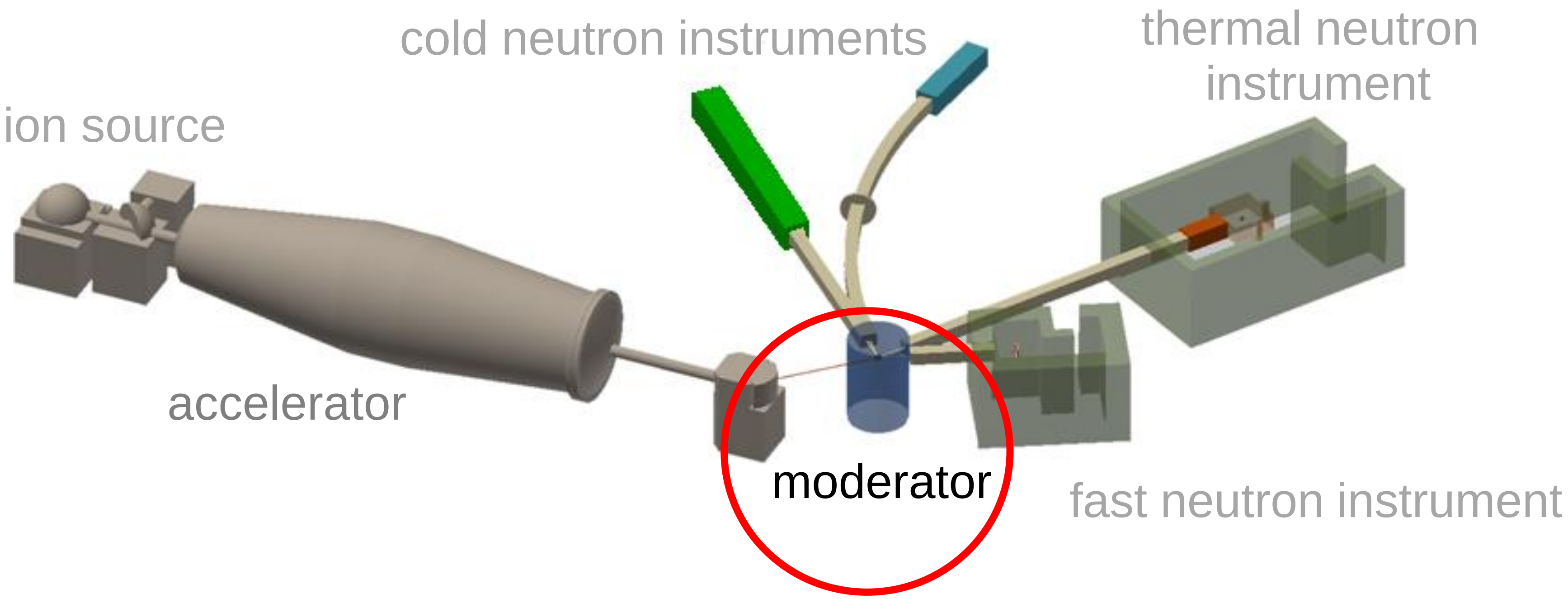


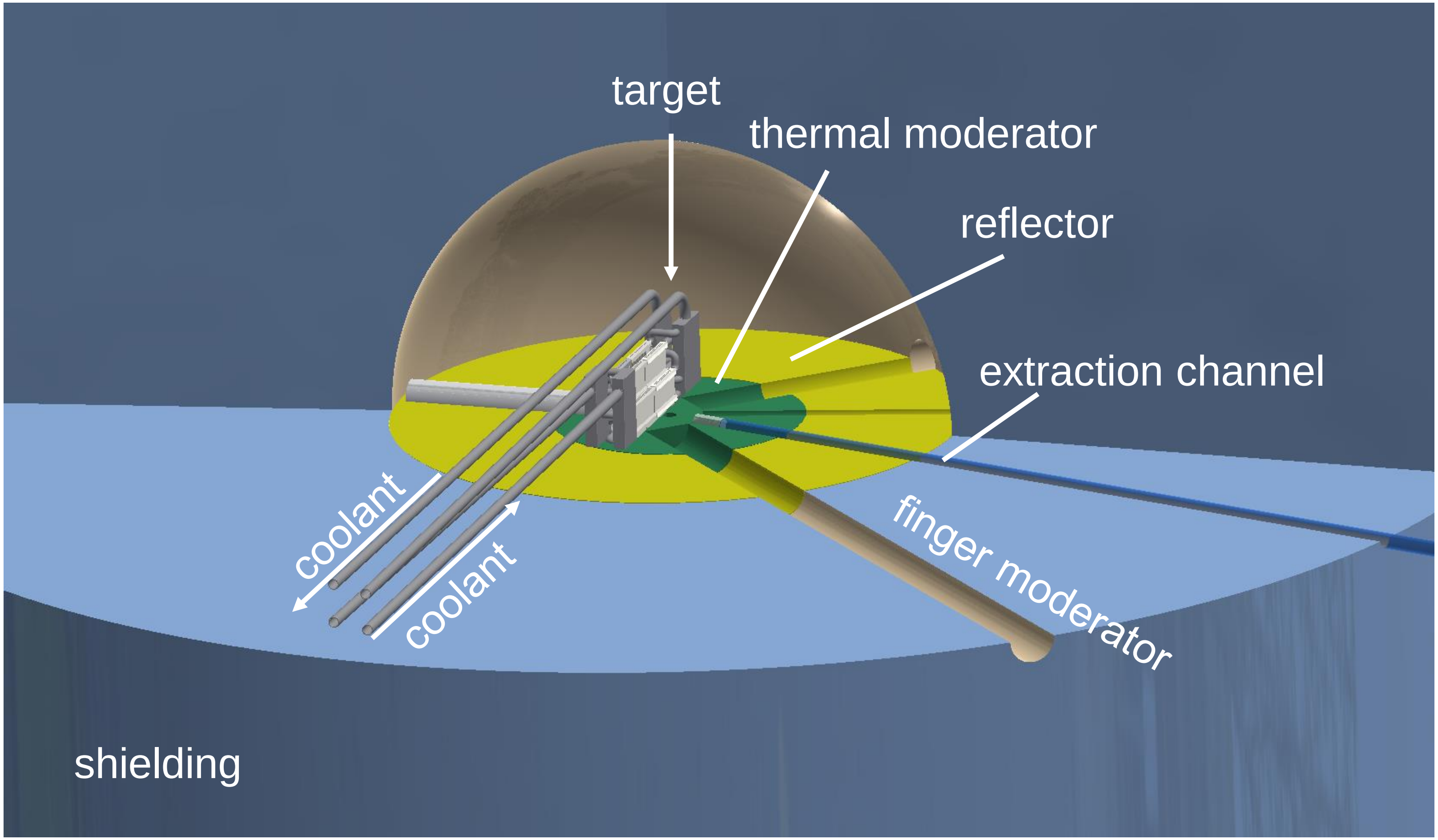
compact

- **Instrument covers a large spatial angle**

HIGH BRILLIANCE NEUTRON SOURCE

Accelerator

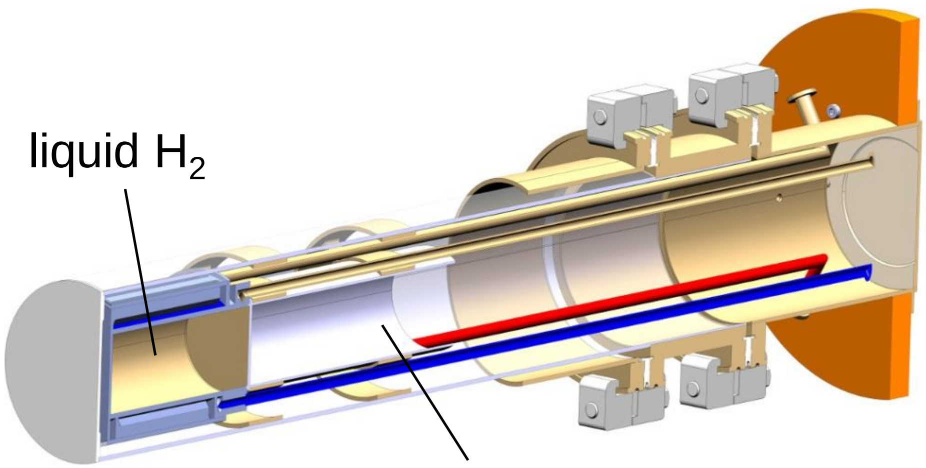



target
thermal moderator
reflector
extraction channel
coolant
coolant
finger moderator
shielding

COLD FINGER -MODERATOR

First liquid H2 moderator with adjustable ortho/para ratio

- cold moderator in thermal neutron maximum (e.g. liquid para H2)
  - mean free path $\lambda_{th} \approx 1$ cm and $\lambda_{cd} \approx 10$ cm
  - optimum shape: tube with
    $R = \lambda_{thermal}$ and $L = \lambda_{cold}$
  - cold neutrons leave with just as much collisions as needed

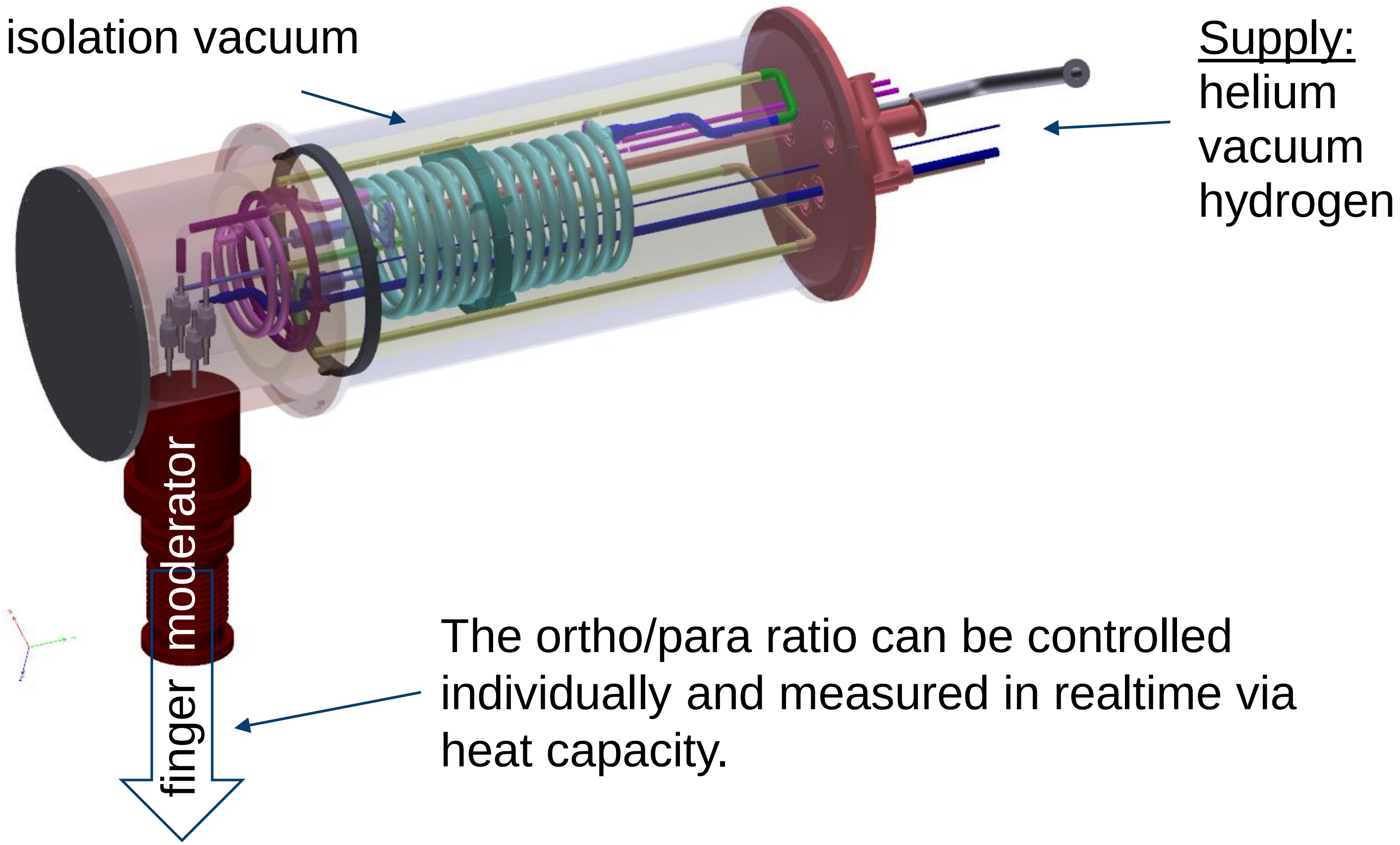


COLD MODERATOR

H2 Moderator - ortho/para mixing cryostat assembly

HYDROGEN MIXING CRYOSTAT

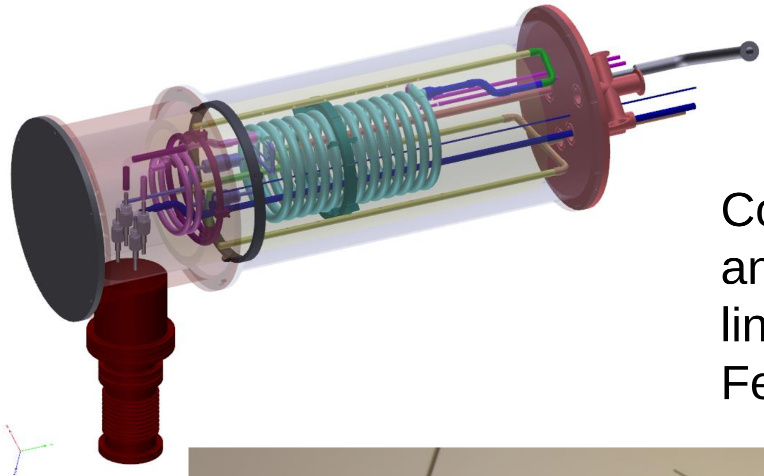
Mixing cryostat



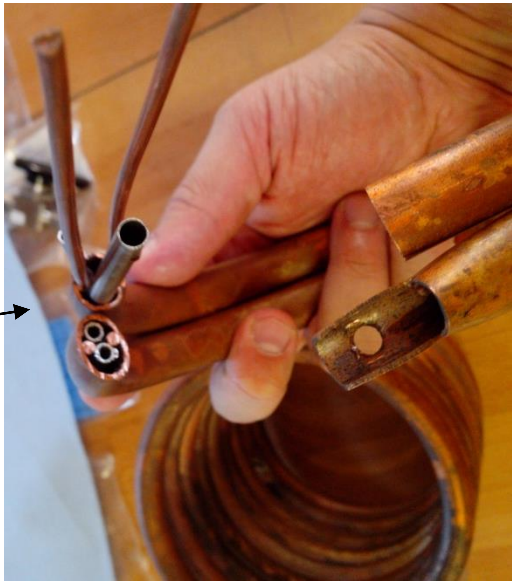
The ortho/para ratio can be controlled individually and measured in realtime via heat capacity.

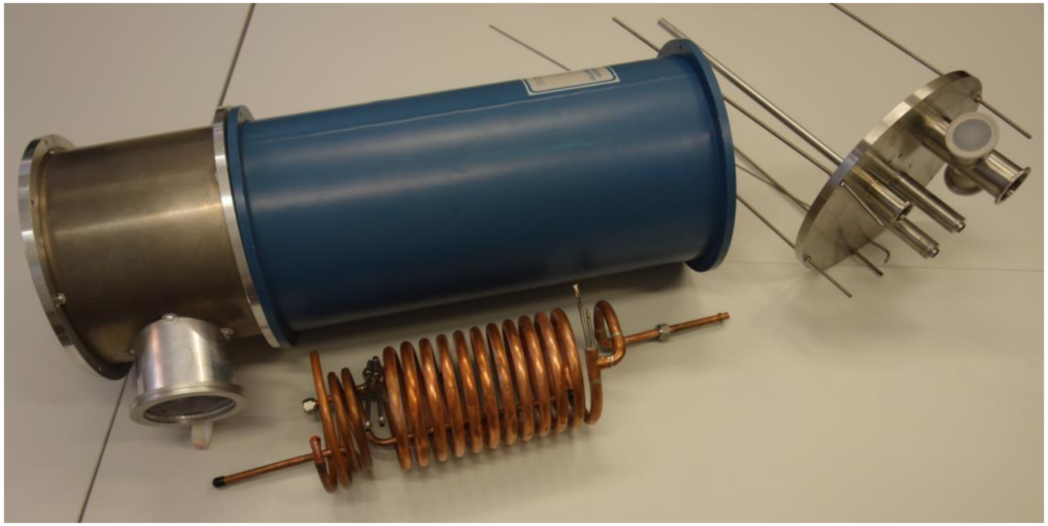
HYDROGEN MIXING CRYOSTAT

Mixing cryostat



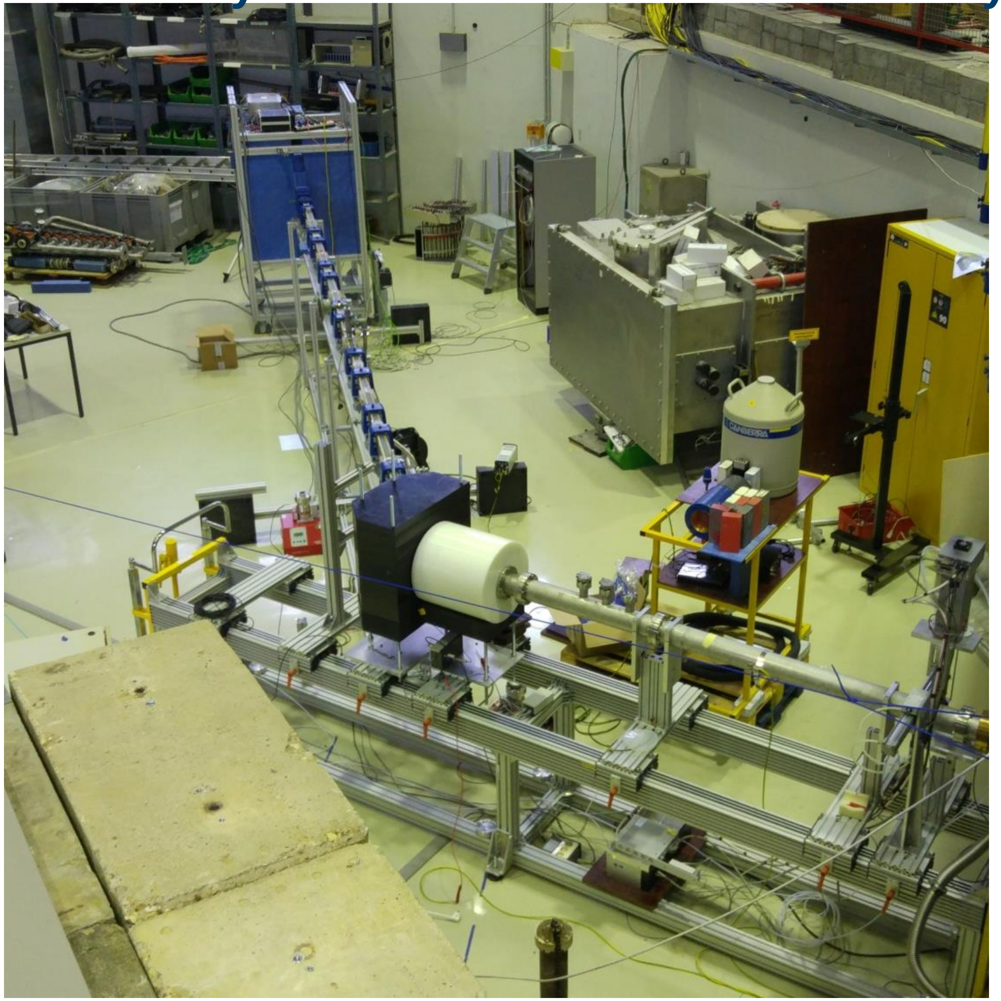
Counterstream of He and two seperate H_2 lines one with Fe(III)oxide catalyst





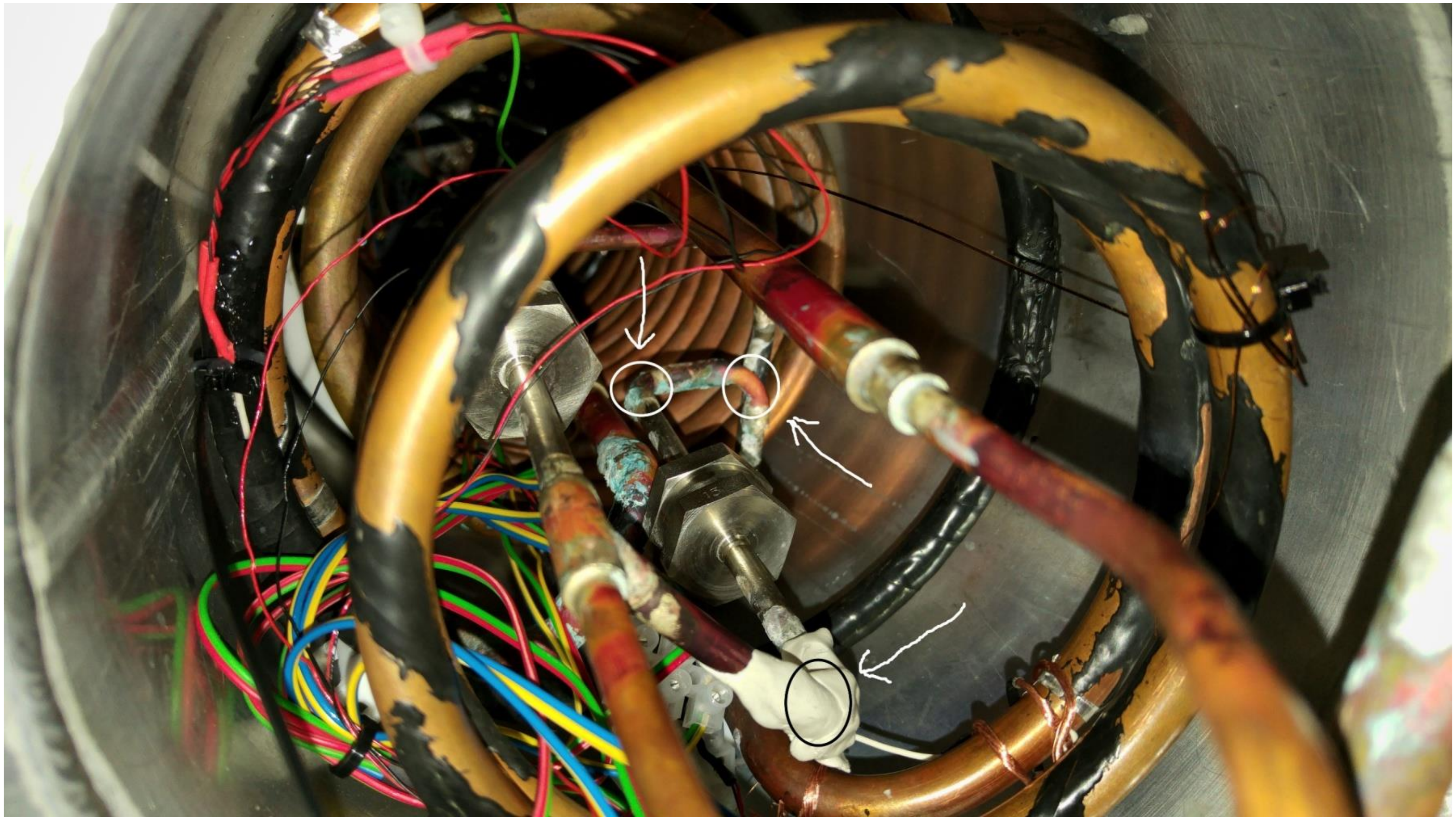
MODERATOR TESTS AT JULIC/COSY

Priliminary H2 moderator tests successfully done



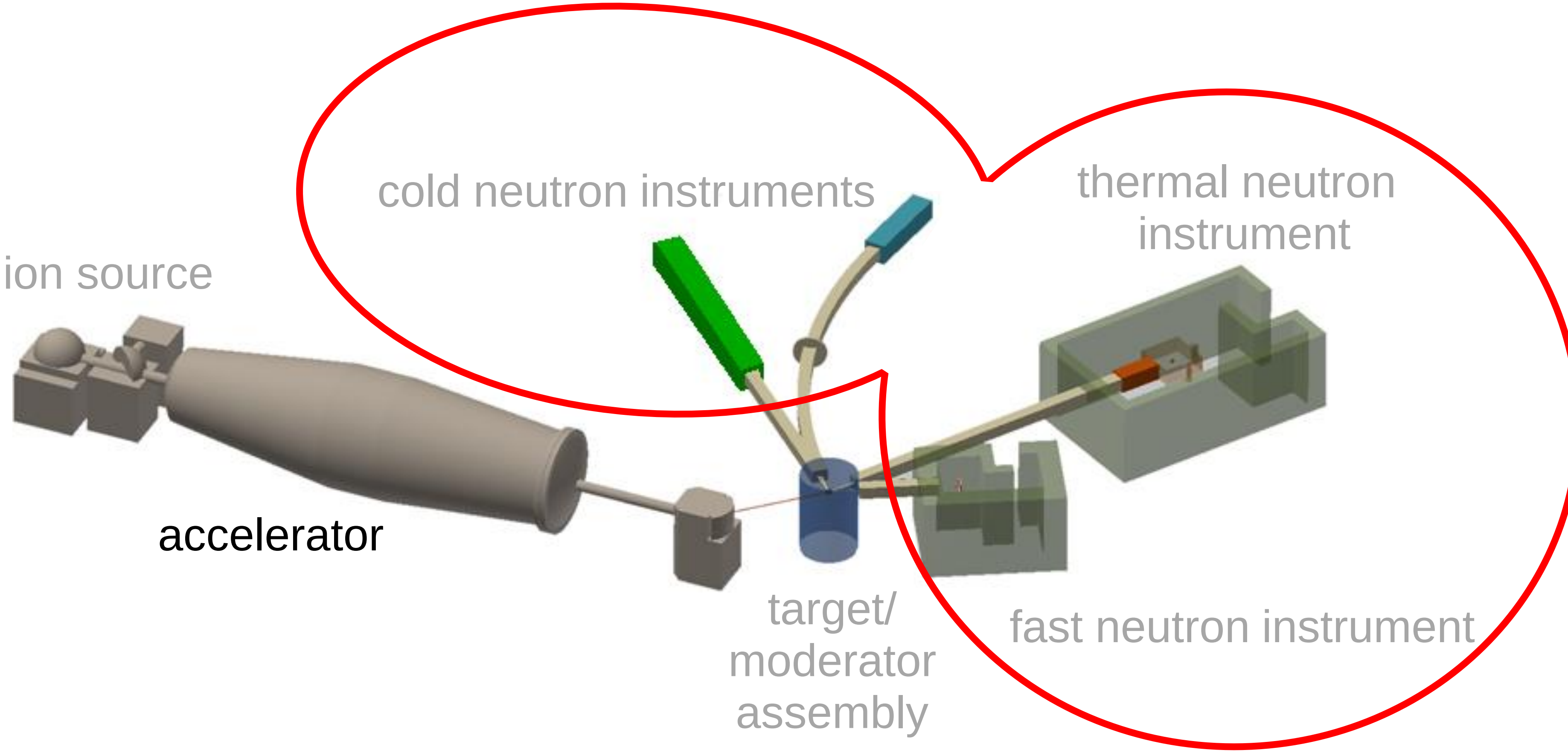
LECKAGE

Leaking difficulties occur – still in leak detection and revision process



HIGH BRILLIANCE NEUTRON SOURCE

Instrumentation



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INSTRUMENTATION

Instrumentation

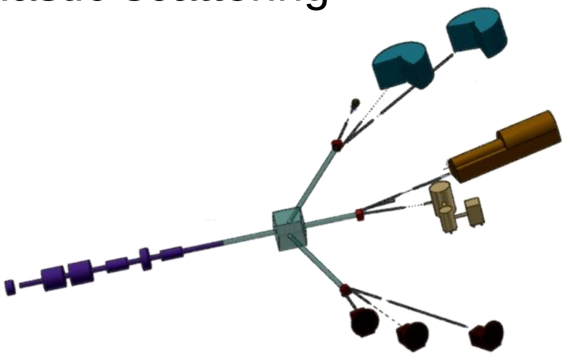
Laboratory facility: NOVA ERA

- basic workhorse instruments for research, education and training
- compromise between resolution and neutron flux at sample position
- 10^3 – 10^5 n /s /cm² at sample pos.
  - ▪ PGNAA
  - ▪ neutron imaging
  - ▪ small angle neutron scattering
  - ▪ powder diffraction
  - ▪ reflectometry

Large-scale facility: HBS

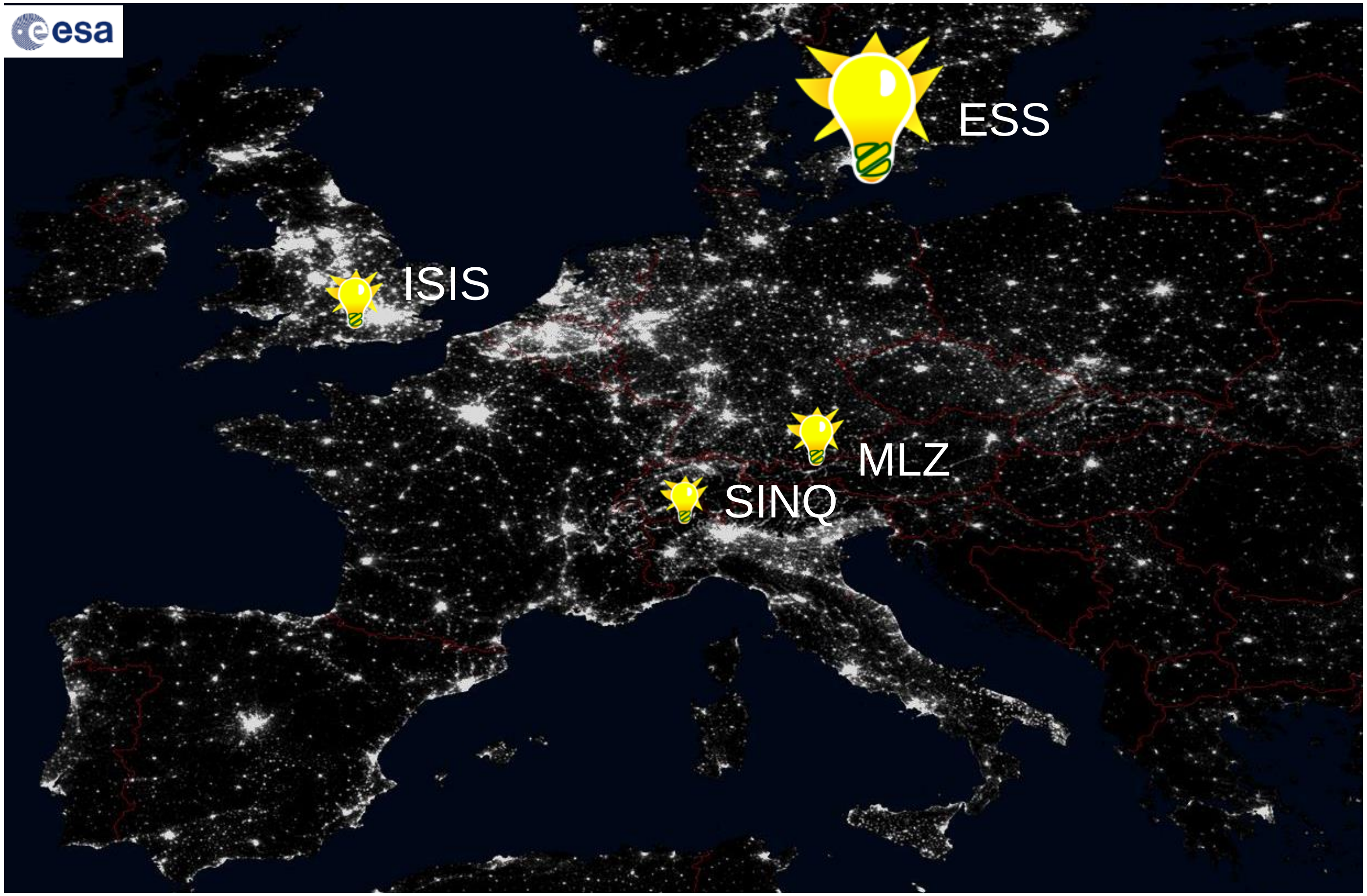
- several target stations
- resolution with reasonable flux
- full suite of instruments with competitive performance
- 10^7 – 10^8 n /s /cm² at sample pos

\+ inelastic scattering



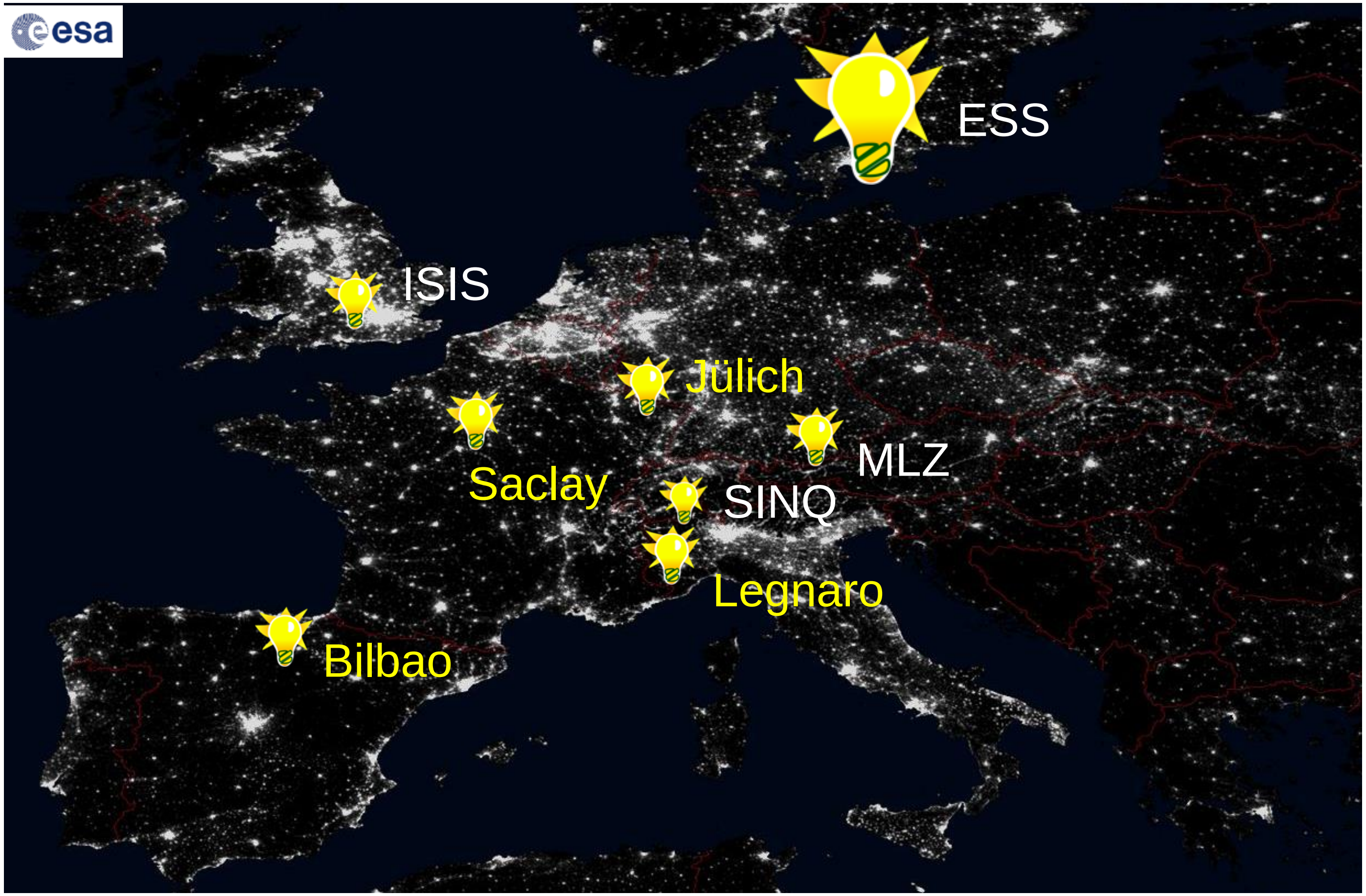
POSSILBLE NEUTRON SCENARIO

after 2030



DESIRED NEUTRON SCENARIO

after 2030: we would like to establish a network of HBS sources



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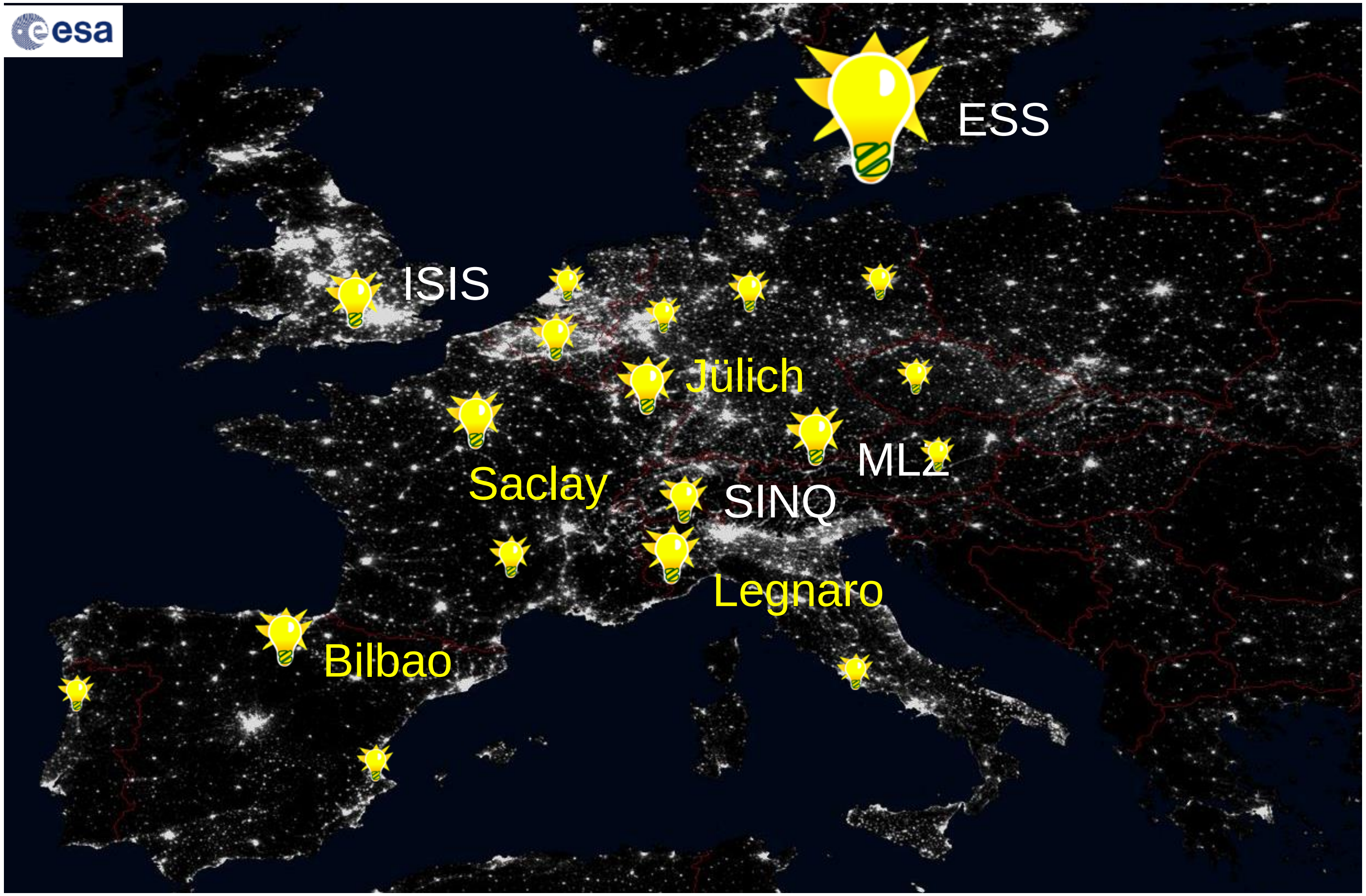

OUTLOOK

- HBS is a accelerator driven pulsed neutron source
- produce less but waste less neutrons
  → due to holistic optimization from instrumentation via moderator and target to the accelerator
  → instrument covers a large spatial angle
- Scalable from low- to medium flux neutron laboratories (except target)
- reasonable costs (Euro per neutron)

- NOVA ERA is the “laboratory” size design – CDR is available
- HBS is the “national facility” size design – CDR will be available end of 2018

HBS TEAM

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T. Cronert
P.-E. Doege
J. Li
E. Mauerhofer
U. Rücker
J. Voigt
P. Zakalek
T. Gutberlet
Th. Brückel

Experimental verification
Instrumentation

ZEA-1:
Y. Bessler
M. Butzek

IKP-4:
D. Prasuhn
O. Felden
R. Gebel
C. Li
M. Bai (GSI)

Nuclear physics
Engineering (cold source)

S. Böhm
R. Nabbi

Nuclear simulations

C. Lange
T. Langnickel
M. Klaus

AKR-2 reactor, liquid H_2