ELENA

European Low Energy accelerator-based Neutron facilities Association

ICANS XXIV
International Collaboration on Advanced Neutron Sources

ESS Bilbao:
Current Status and Perspectives

Mario Pérez
ESS Bilbao / ELENA Association
Dongguan, China, 1 November 2023

Who we are?

International Research and Development center for Particle Accelerator and Neutron Science and Technologies which generates knowledge and added value through the in-kind contribution to the European Spallation Neutron Source, in Lund (Sweden).

Employees

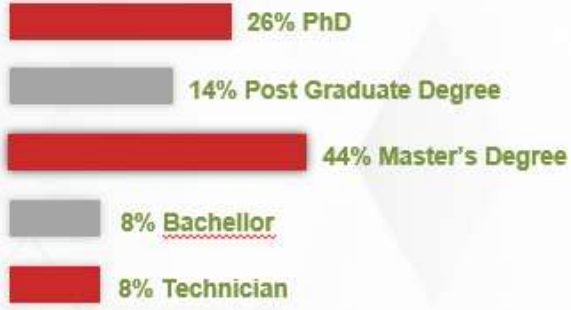
47

Age average: 43

28% women

72% men

Qualification



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Where we are?

Headquarters

Parque Tecnológico de Zamudio (Bilbao, Bizkaia)

R&D Center

Parque Tecnológico de Zamudio (Bilbao, Bizkaia)

AWF

Pol. Ind. Júndiz. Vitoria, Gasteiz

Madrid Satellite

Garena Tower (Alcala de Henares)

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ESS In Kind contribution

And other International Collaborations

In-Kind Contribution

MEBT

Accelerating element: complete subsystem that goes after the RFQ and integrates: design, manufacturing, diagnostics, control, assembly and testing.

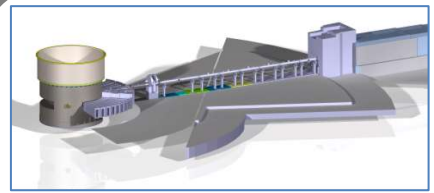
RF Systems

RF chains: 1 for RFQ and 5 for DTL. Composed by klystrons, modulators, loads, waveguides, interlocks and LLRF

TARGET

The spallation process takes place when the accelerated proton beam hits the Tungsten bricks of the 11-tonne target wheel. This will produce neutron brightness for scientific experiments across multiple disciplines.

MIRACLES Instrument



Time-of-Flight backscattering instrument for polymer science, energy materials, and magnetism studies.

ACCELERATOR

ESS In-Kind Contribution - Accelerator

ESS In-Kind Contribution – Target

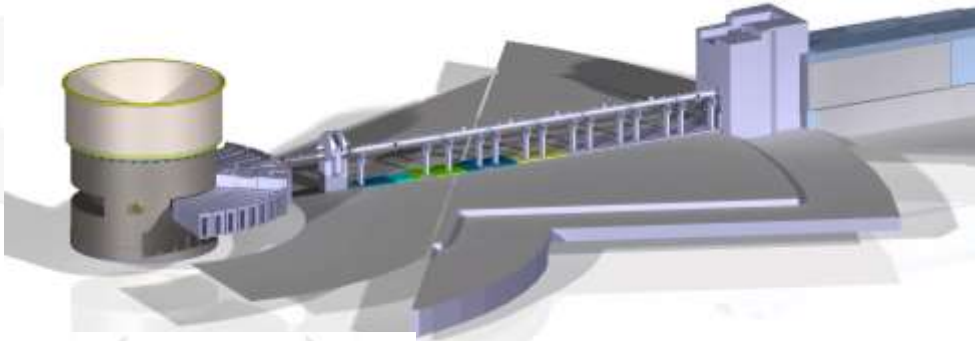


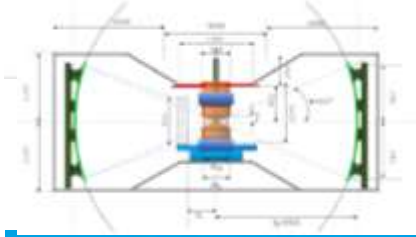


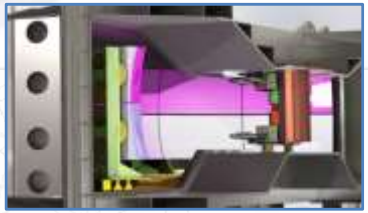


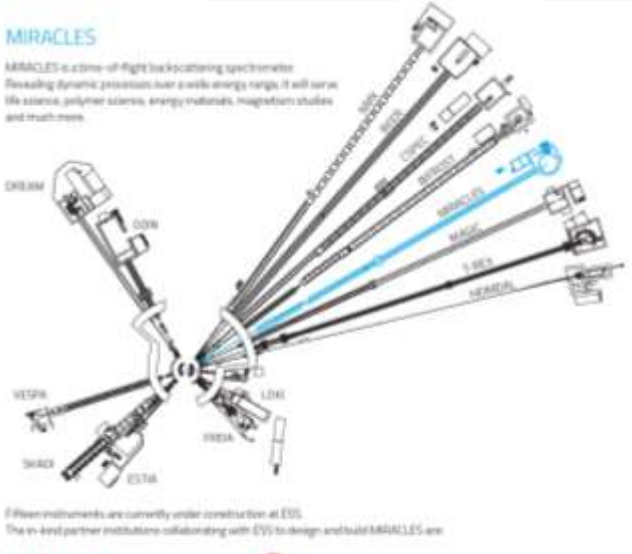


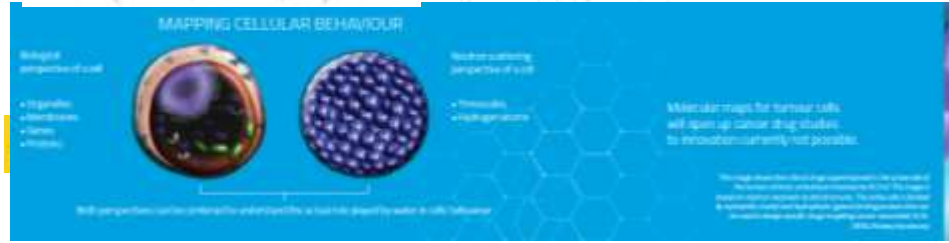

ESS In-Kind Contribution - Intruments

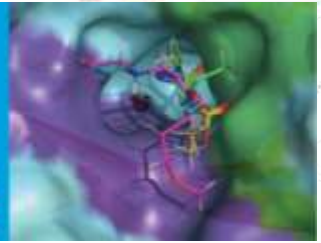












OTHER
INTERNATIONAL PROJECTS

IFMIF-DONES ESPAÑA

iter
china eu india japan korea russia usa

CERN

Muti_Harmonic Buncher
ISOLDE ISRS

sck cen
Exploring a better tomorrow

Collaboration agreement on particle accelerator technology development between ESS Bilbao and the Belgian Nuclear Research Centre (SCK CEN) for Myrrha project.

ISOLDE CSIC ESS bilbao

ESSνSB ESS NEUTRINO SUPER BEAM

MYRRHA

ESS Neutrino Super Beam Project

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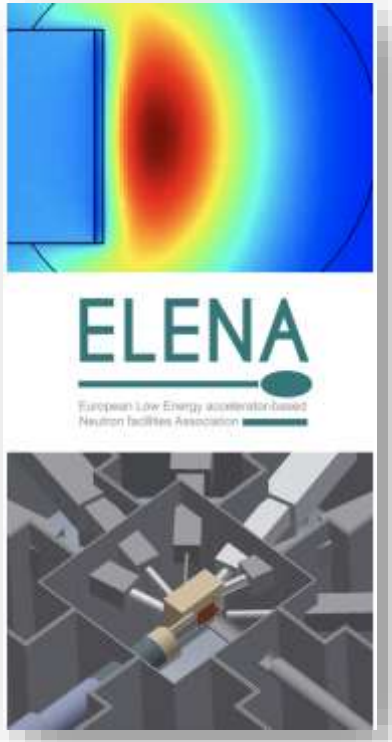
ELENA Association

Mission and Members

ELENA Mission

- **ELENA is an association to promote cooperation within Europe in the field of neutron sources based on an accelerator and a stripping reaction to produce neutrons**
- created on September 10th, 2020
- **Commitment of Members**: initiate
  - ✓ collaborations
  - ✓ conferences, workshops and meetings

  in order to create an effective eco-system for research and applications in all areas of science and industry around these neutron sources.



ELENA Current Members

Current members from

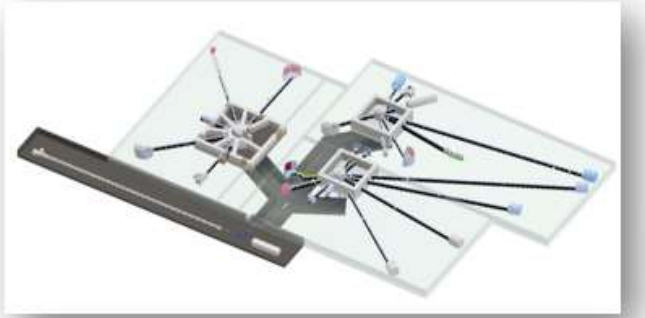
- ✓ESS Bilbao, Spain
  www.essbilbao.org
- ✓Institutt for Energiteknikk (IFE), Norway
  www.ife.no/en/
- ✓Jülich Centre for Neutron Science (JCNS), Germany
  www.fz-juelich.de/jcns/EN
- ✓ Laboratoire Léon Brillouin (LLB), France
  www-llb.cea.fr/en/
- ✓ Laboratori Nazionali di Legnaro (LNL), Italy
  www.lnl.infn.it
- ✓ Mirrotron Ltd., Hungary
  www.mirrotron.com/en
- ✓ SARAF Accellerator Facility, Israel
  nrcn.gov.il
- ✓ Uppsala Universitet, Sweden
  www.uu.se

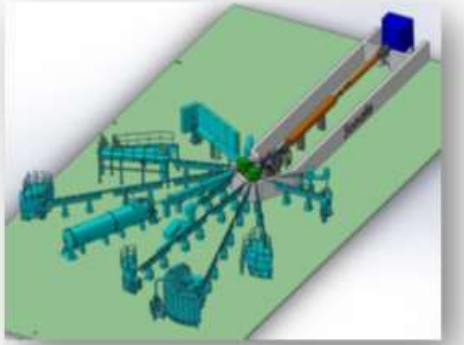
ELENA Projects

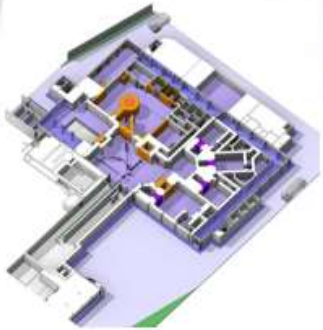
ELENA
European Low Energy accelerator-based Neutron facilities Association

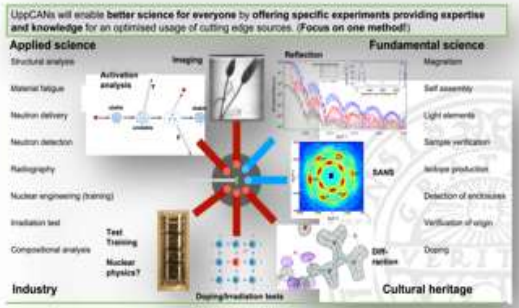
scalable

- **HBS at JCNS**
  100 mA, 70 MeV, protons, Ta target,
  3 target stations, 18 instruments
- **ICONE at LLB, CEA, CNRS**
  60 mA, 30 MeV, protons, Be target,
  2 target stations, 11 instruments
- **ARGITU at ESS Bilbao**
  32 mA, 31.5 MeV, protons,
  1 target station, 3 instrumens
- **SARAF at SOREQ**
  5 mA, 40 MeV, protons / deuterons,
  liquid metal target, 5 instruments
- **NEPIR at LNL Legnaro**
  0.75 mA, 70 MeV, protons,
  Be/W target, irradiation facility
- **LvB at Mirrotron Ltd.**
  20 mA, 8 MeV, protons,
  Li target, target stations









European Neutron Ecosystem

LENS Vision Landscape Document
The Role of HiCANS

LENS: League of advanced European Neutron Sources

https://lens-initiative.org/

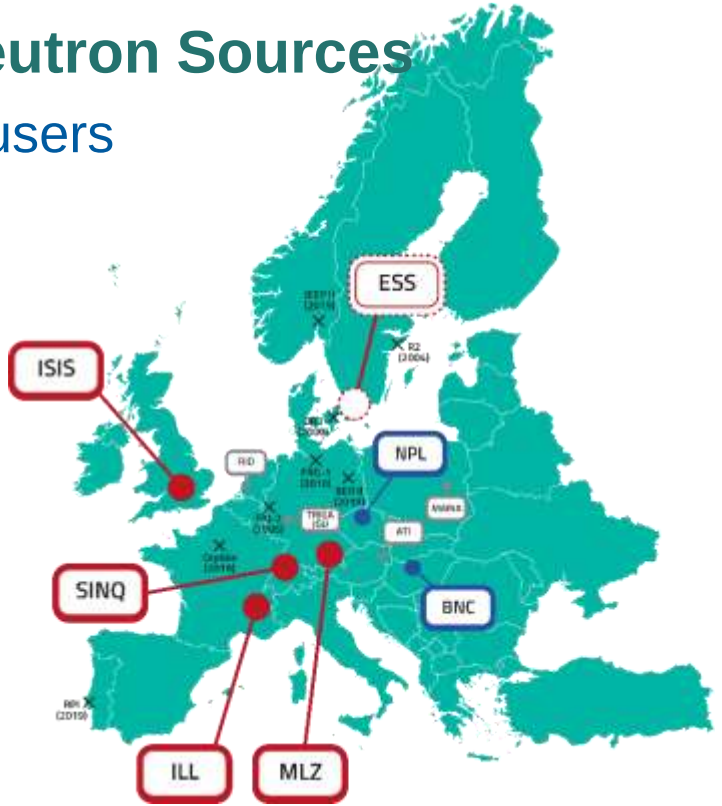
LENS LEAGUE OF ADVANCED EUROPEAN NEUTRON SOURCES

The League of advanced European Neutron Sources (LENS) has the not-for-profit purpose of promoting the cooperation and projects between European-level neutron infrastructure providers that offer a transnational user programme.

LENS: League of advanced European Neutron Sources

How to maintain a viable ecosystem for > 5000 users

- since 2000:
  8 older reactor-based facilities closed
- Neutron knowledge centers created
  (JCNS, GEMS, LLB, IFE)
- 2004:
  1 new research reactor becomes
  critical (FRM II @ MLZ)
- 2030 / 33:
  shut-down of HFR @ ILL
  (≈ 60 years after first criticality!)
  according to present planning



Neutron facilities in Europe. Larger facilities indicated in red. Sources that are no longer operating are marked with an X. ESS is under construction. © LENS – Stephanie Chapman

European Spallation Source ESS

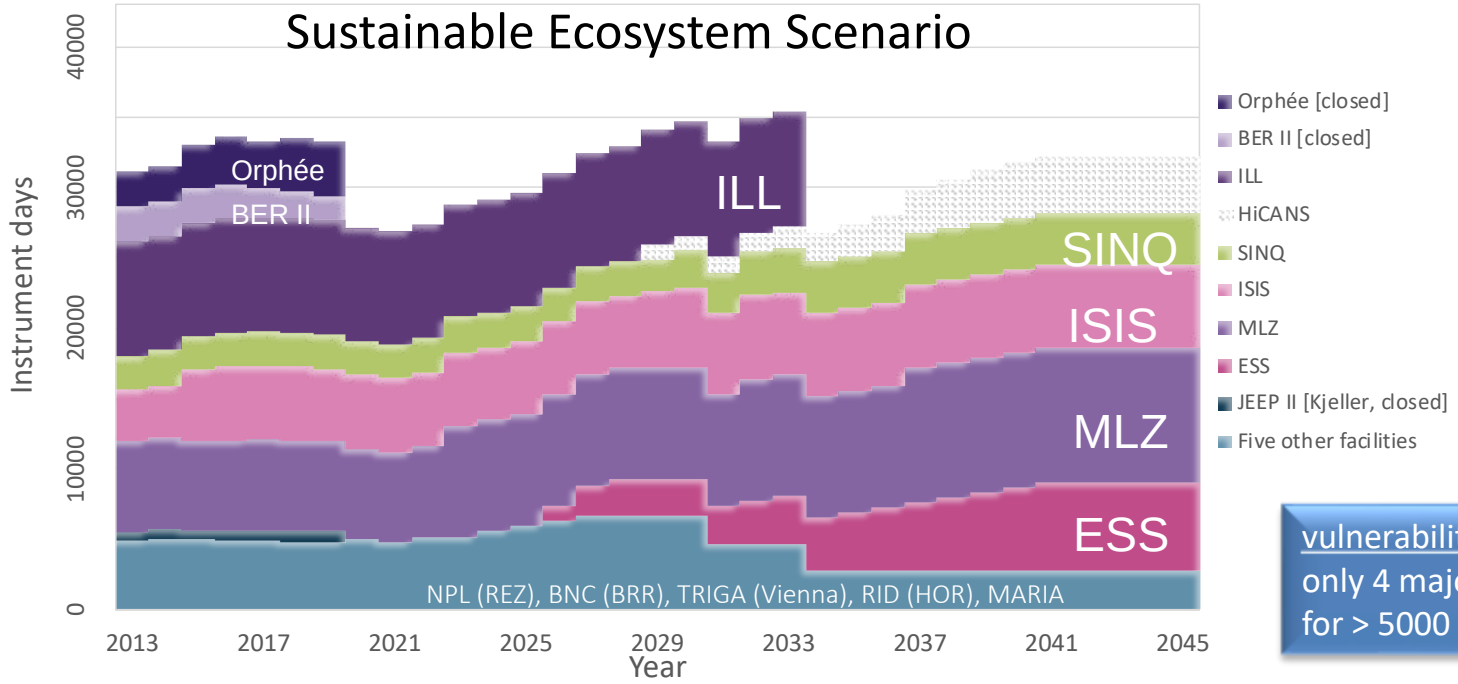
The Future European Flagship Facility

- not more of the same, but entirely new experiments!
- initially 15 instruments for > 5000 users
- provides capability, only limited capacity
- 13 founding members

vulnerability past 2033:
only 4 major sources left
(ESS, MLZ, ISIS, SINQ)
for > 5000 users

LENS: League of advanced European Neutron Sources

How to maintain a viable ecosystem for > 5000 users



vulnerability:
only 4 major sources left
for > 5000 users

LENS Vision Lanscape

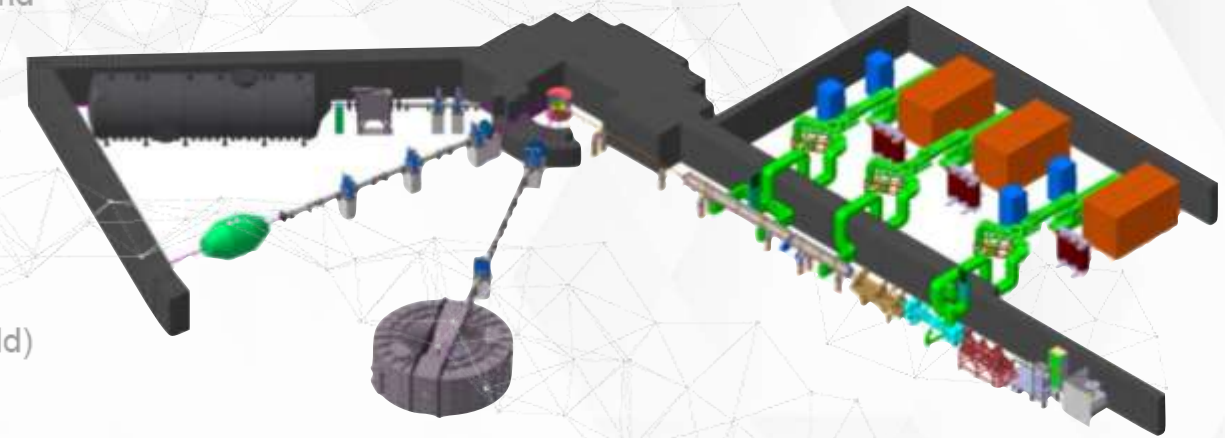
- **"The only route for entirely new facilities with significant capacity are High Current Accelerator-driven Neutron Sources (HiCANS), which could occupy the role played by national reactor-based sources in the past….".**
- *"…Due to their considerable flexibility - in terms of cost, capacity and capability - HiCANS could play an important role in sustaining the European neutron science ecosystem..."*

ARGITU

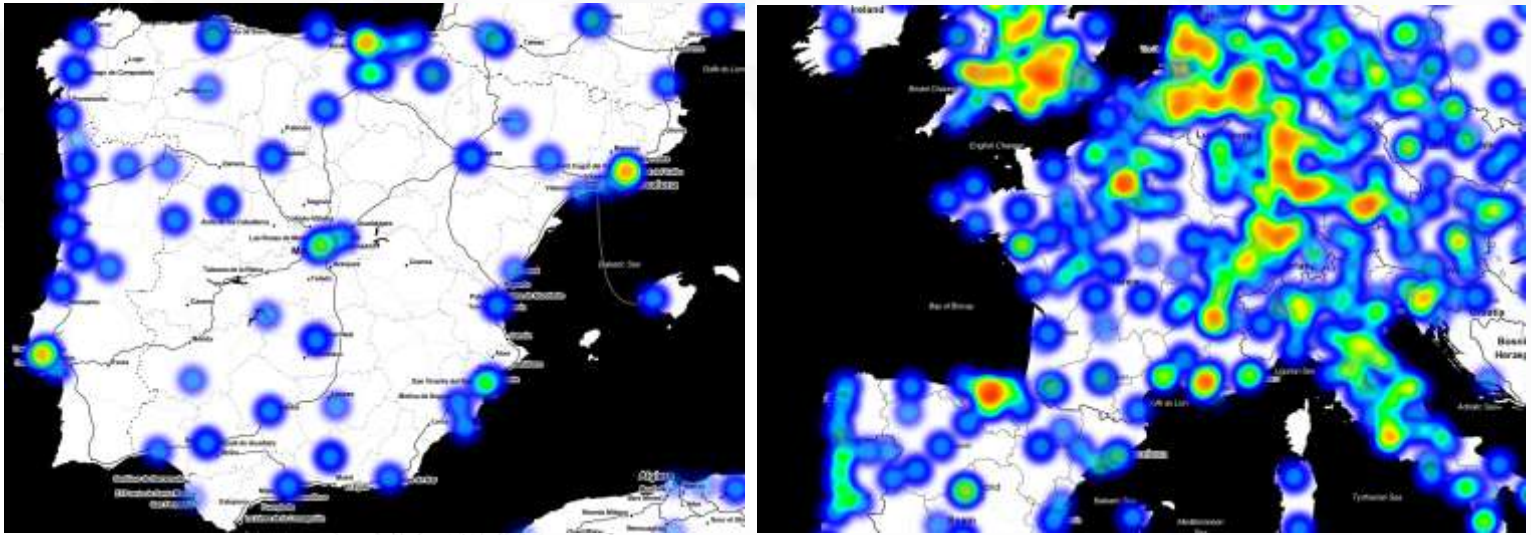
A unique infrastructure fostering the R&D ecosystem in Euskadi and Beyond

ARGITU, Baseline Design - Overview

- Dedicated proton accelerator: energy 31.5 MeV and current 32 mA
- Pulsed beam at frequency f= 30 Hz and pulse length Dt=1.5 ms (DC=4.5%; P=45 kW)
- Compact Target-Moderator-Reflector (TMR) system.
- Beryllium target.
- Dedicated moderators, optimized for each neutron instrument (thermal, cold)
- Up to 4 neutron instruments per TMR



Fostering Neutronic R&D ecosystem…



Heat maps of neutron scientists, in terms of their **scientific productivity**, as a function of their home institutions in Spain (left) and in western Europe (right), denoting a **leading role of Basque scientists in the use of neutron scattering tools for research and development activities**

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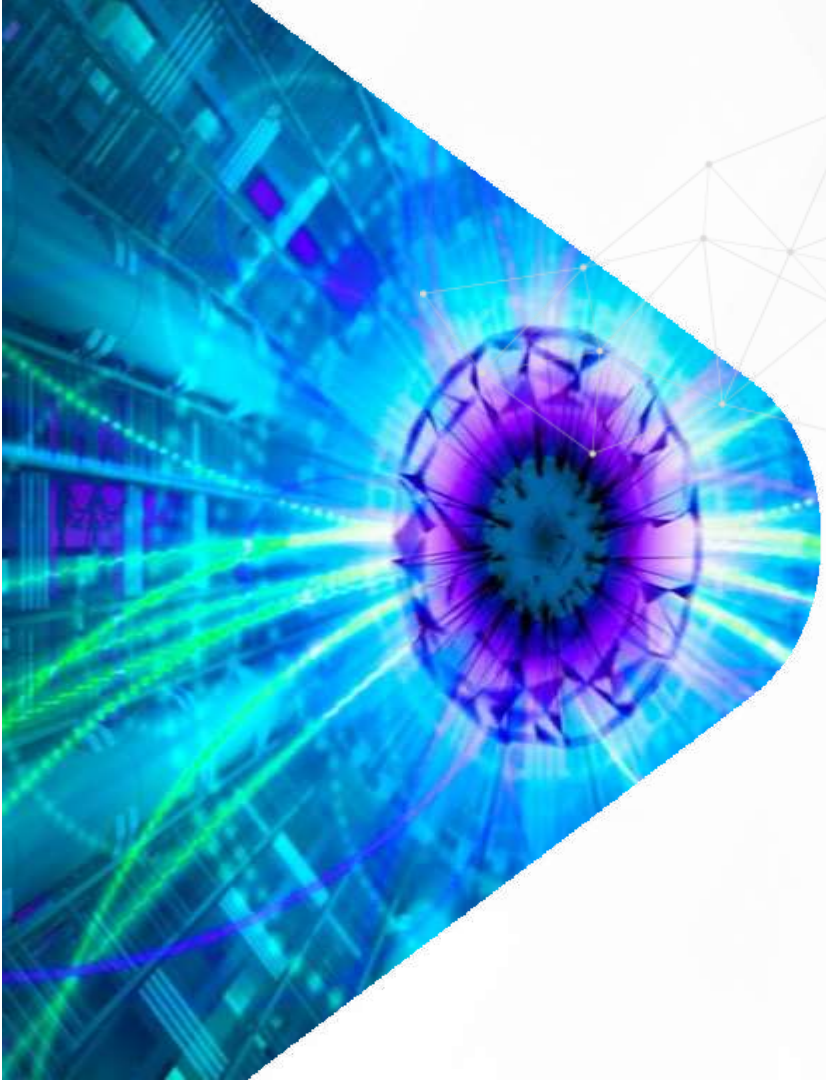
…aligned with IKUR strategy 2030



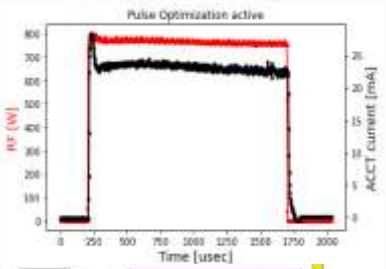
ARGITU
Accelerator System

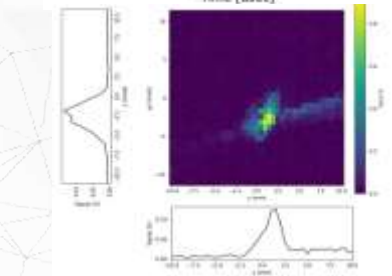
Current Status and Perspectives

Injector – Ion Source + LEBT

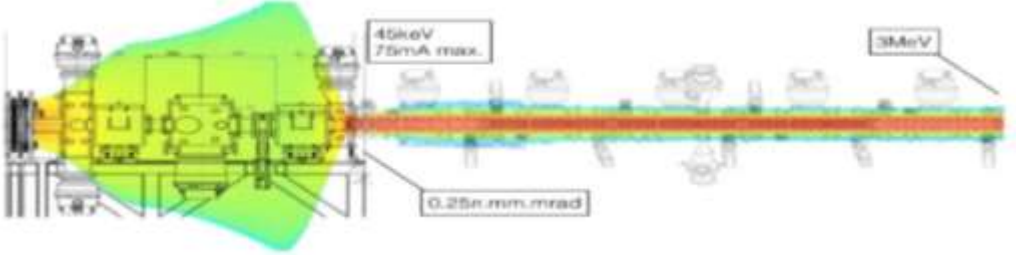
ISHP

- 45 KeV Proton beam
- Up to 30 mA
- Pulse length up to 2 msec
- Pulse repetition rate up to 20 Hz





RFQ – Medium-Term Goal: 3 MeV beam



- Segments #2,#3 finished, and #4 expected soon
- Power couplers v1.0 tested in low and high power
- Tuning algorithm improved
- Beadpull and tuning during 2024

Table 1: ARGITU-RFQ Main Specifications

Parameter	Value
Specimen	H+
Beam current	32 mA
Beam energy	45 keV→3 MeV
RF Frequency	352.2 MHz
Pulse Operation	30 Hz; 1.5 ms; 4.5 %
Intervane Voltage	85 kV
Kilpatrick	1.85
Input emittance	0.25 π mm rad

RF Power System

- Long term operation of the Klystron is being carried out at CPI at California
- Delivery to ESS Bilbao is planned before the end of 2023.
- Modulator, Waveguides and other auxiliaries are ready at our RF Test Stand in Bilbao.
- RF Power System integrated test is scheduled to run in parallel with the RFQ tunning activites

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ARGITU
TMR System

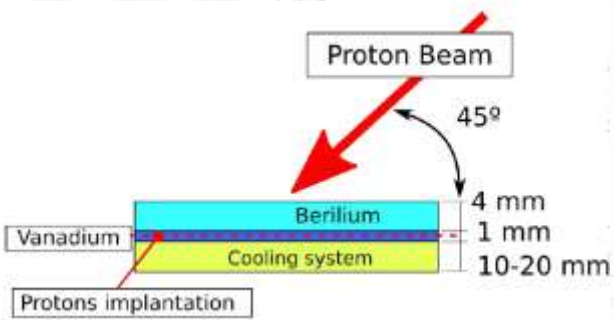
Current Status and Perspectives

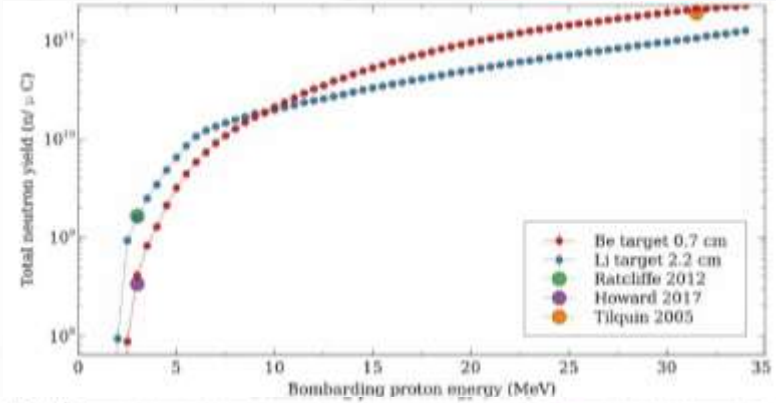
The Target Station: Design

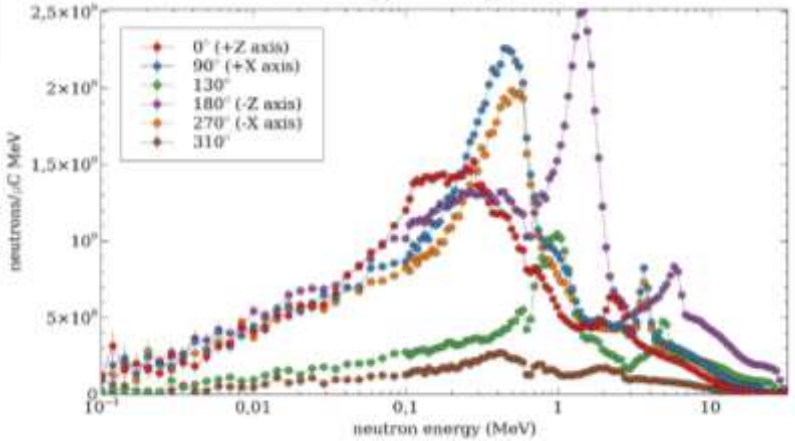
Beryllium maximize the neutron yield for 32 MeV protons (~ 2-3 10^{14} n/s)

If the Brag peak is in the Be target, blistering will be produced within few hours of operation. 1 mm vanadium layer is added to stop protons.

Introducing 45º between Target and beam the cooling area is increased.





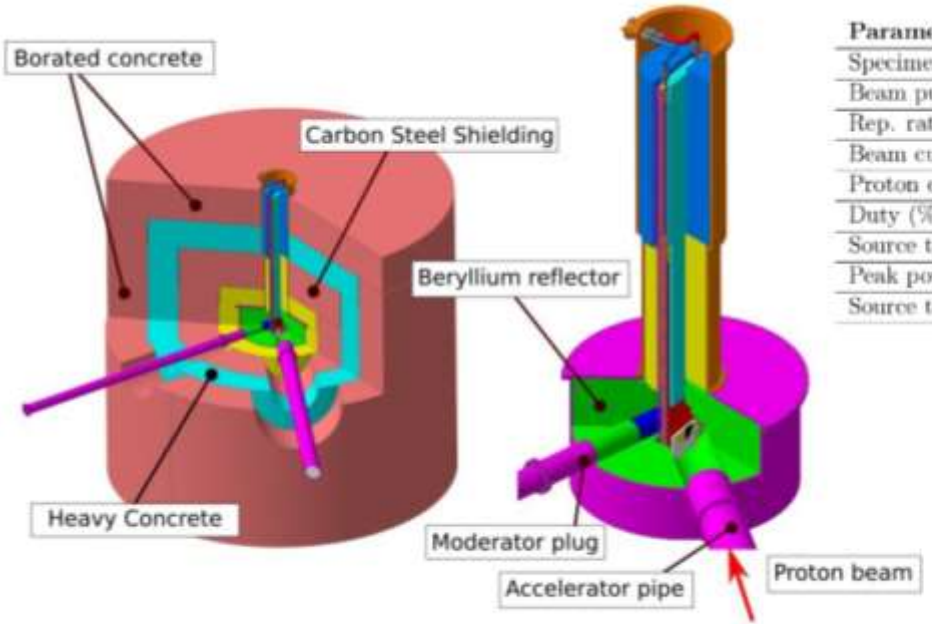


The Target Station: General Layout

In order to maximize the available space for instruments, the Target is designed for vertical extraction.

Target and moderators integrated in a beryllium reflector to increase the neutron moderation efficiency.

The TMR will be surrounded by an aluminum vessel and a 1.5 m diameter shielding of different layers



Parameter	Values
Specimen	H^+
Beam pulse (ms)	1.5
Rep. rate (Hz)	30
Beam current (mA)	32
Proton energy (MeV)	31.5
Duty (%)	4.5
Source term (H^+/s)	8.96E15
Peak power (KW)	1007.2
Source term (H^+/MW)	1.98E17

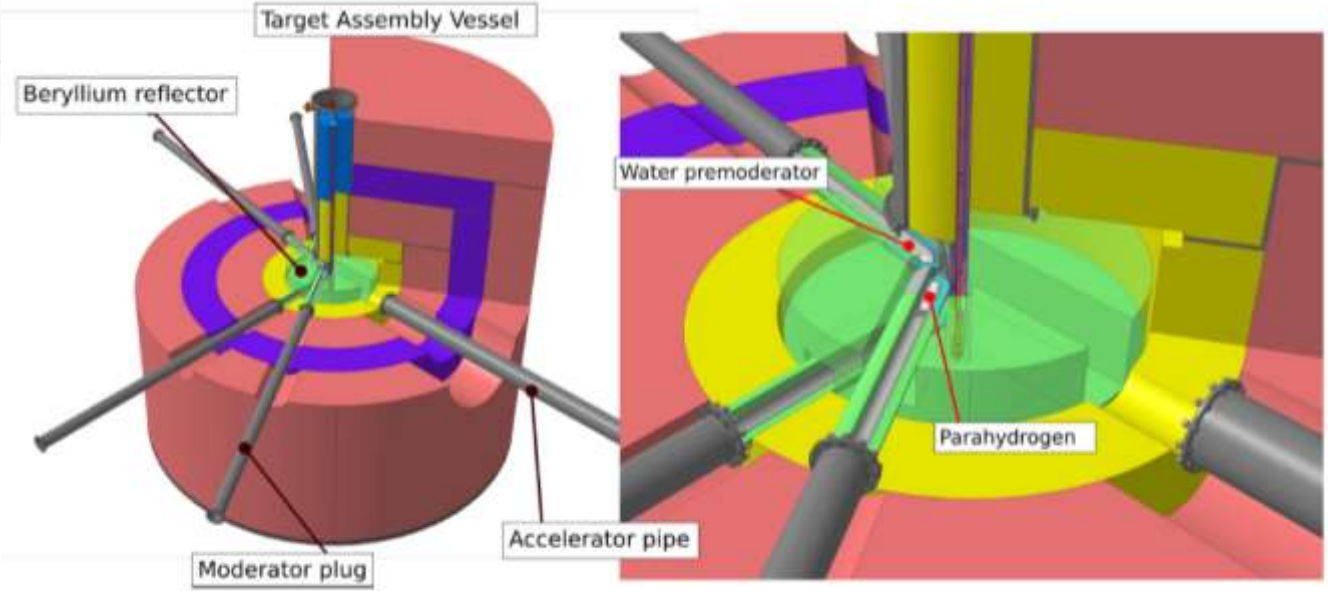
The total expected deposition in the Target is **42.5 kW**

The Target Station: Moderator

Even though the total neutron yield of the source is relatively low, the neutrons will be distributed in a small volume.

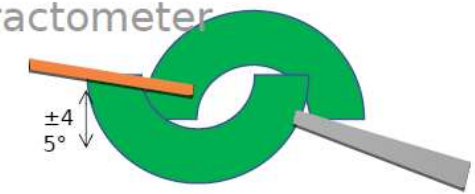
The “1D finger moderator ” configuration will allow to define a dedicated moderator per instrument. An optimization process performed to proposed moderators for 4 instrument lines and a beryllium reflector.

The moderators are placed in two different planes symmetrically from the proton beam

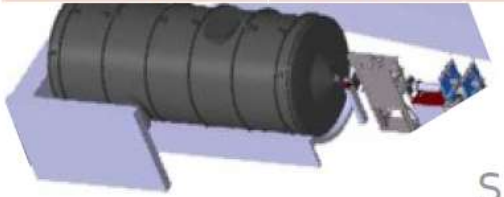


Thermal Powder Diffractometer

Single Crystal Diffractometer

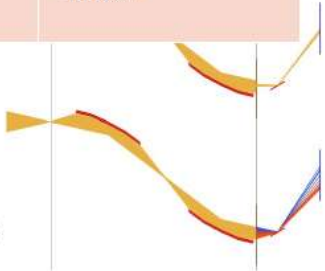


Instrument Parameters	Thermal Powder Diffactometer	Single Crystal Diffractometer	SANS	Reflectometer
Moderator	H_2O	H_2O/p-H_2	p-H_2	p-H_2
Length	45 m	30 m	1.5-10 m	~3 m
Bandwidth $\Delta\lambda$	0.6-2.6 Å	1.5-5 Å	~7 Å	2.5-15 Å
Detectors & Sample-det. dist.	^{3}He (alt. ^{10}B) 1.5 m	^{3}He (alt. ^{10}B) 1 m	^{3}He (alt. ^{10}B) ~1 m^2	2D ^{3}He (alt. ^{10}B) ~0,5 x 0,25 m^2
Scattering range	$\Delta 2\theta$ ~ 3-175 °	$\Delta 2\theta$ ~ 3-175 ° hor. (±45° vert.)	Q ~ 10^{-3}-1 Å^{-1} d ~ 1-300 nm	Q ~ 0.004-0.4 Å^{-1} (vertical)
Divergence	0.5 x 2 °	0.8 x 0.8 °	0.4 x 0.4 °	0.2 x 2 °
$\Delta d/d$ (High res.) $\Delta d/d$ (High flux)	<0.01 for 2θ> 90 ° ~0.02 for 2θ> 90 °	<0.01 for 2θ> 90 ° ~0.02 for 2θ> 90 °	<10%	<10%



SANS

Reflectome



The Target Station: Moderator

A comparison with other facilities, gives ARGITU a 50%-time average flux than that of ISIS-TS2 H/CH4 moderator

	Neutrons below 400 meV				
	Power [kW]	Rep. R. [Hz]	Surface [cm^2]	N. intensity [n/cm^2 s sr]	N. intensity [n/cm^2 ps sr]
JSNS C. Hydrogen	300	25	10w x 10h	1.3E+12	5.1E+10
	1000	25	10w x 10h	4.5E+12	1.8E+11
SNS C. Hydrogen	1000	60	12w x 10h	2.1E+12	3.5E+10
	1400	60	12w x 10h	3.0E+12	4.9E+10
ISIS-TS2 H/CH4, gro.	48	10	8,3w x 3,0h	5.0E+11	5.4E+10
ISIS-TS2 H/CH4, hyd.	48	10	12w x 11h	**3.0E+11**	3.0E+10
ARGITU 2022 1 Nline (cold)	50	30	Ø 5 cm	1.6E+11	5.1E+09
ARGITU 2022 4 Nlines (SANS)	50	30	Ø 3 cm	**1.5E+11**	4.9E+09

ARGITU
Instrument Suite

Current Status and Perspectives

CFM

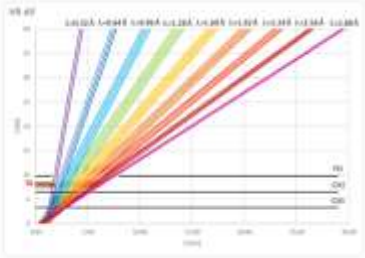
BASQUE CENTER FOR MATERIALS, APPLICATIONS & NANOSTRUCTURES
BCMATERIALS

BIOFISIKA
Basque Centre for Biophysics

Diffractometers (2)

- A versatile thermal (or bispectral) powder diffractometer to cover a wide range of momentum transfer.
- A bispectral diffractometer that can cover both powder and single crystal capabilities.

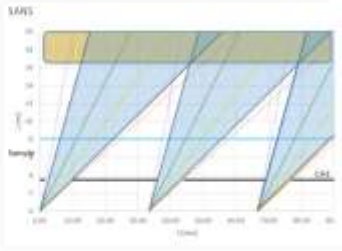
Instrument Parameters	
Source (moderator)	H_2O (solid CH_4 for bispectral)
Length	22-40 m
Wavelength band $\Delta\lambda$	0.6-1.6 Å (thermal) 0.6-3 Å (bispectral)
Detectors and sample detectors distance	3He (ø1. 10ft) 1-1.5 m
Detector coverage $\Delta2\theta$	9-170°
High resolution $\Delta d/d$	<0.01 for 2θ=90°
High flux $\Delta d/d$	~0.02 for 2θ=90°



SANS

- TOF-SANS instruments~8-10 m detector tank, with a 1 m^2 pixelated 3He tube detector array).
- Capable to ensure a lower threshold of the momentum transfer of about $Q \sim 10^{-1}$ Å^{-1}.
- Cold neutrons: bender or Be filter at the neutron beam extraction.

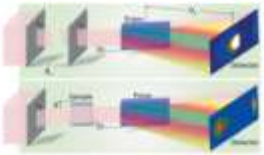
Instrument Parameters	
Source (moderator)	H_2
Sample-detector distance	1-8/10 m
Wavelength band $\Delta\lambda$	~7-8 Å (normal mode)
Detectors and sample detector area	3He (ø1. 10ft) ~1 m^2
Q range	~10^{-1} - 1 Å^{-1}
D (nm)	0.5-400
Resolution $\Delta L/L$	~10%



Reflectometer

- Typical samples sizes: liquid samples (10 cm x 3 cm) or solid/liquid sample cells (8 cm x 5 cm).
- Broad divergence range and a broad wavelength band (in the 2.5 – 16 Å range) to the sample position.
- 2D ^{3}He tube detector array (500 x 250 mm, resolution 0.5 x 2.5 mm)
- Distance sample-detector ~3m.
- New instrument concepts?
  - ❑ SELENE guide (ESTIA, ESS).
  - ❑ Refractive prismatic analyzer (RAINBOWS, ILL).

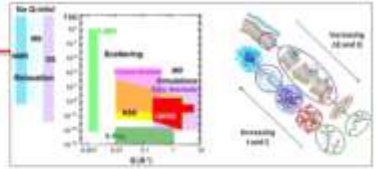
Instrument Parameters	
Source (moderator)	H_2
Sample-detector length	~3 m
Wavelength range, λ	2.5-16 Å
Detectors and sample detector area	2D 3He (ø1. 10ft) ~0.5 x 0.25 m^2
Q range	~0.006-0.6 Å^{-1}
Sample orientation	Horizontal
Resolution $\Delta L/L$	<10%

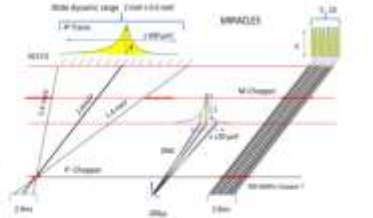


ESTIA: ESS Instrument Proposal
R. Cubitt et al., J. Appl. Cryst. (2018). 51, 257–283

Spectrometer?

- Neutron spectroscopy is a powerful tool to probe the dynamics of materials.
- A significant number of scientists use this technique.
- Moderate flux at sample represents a challenge.
- Potential options will envision a QENS spectrometer:
  - ❑ Crystal spectrometer (TOF Backscattering) with a flexible choice of dynamic range.
  - ❑ NSE (hungry of flux).
- To increase the flux at sample: pulse multiplication, guide splitting,...
- To improve neutron collection after sample: multichannel concept (MultiMUSES).





V. García Sakai, A. Arbe, Curr. Op. Colloid & Interf. Sci. 14 381 (2009)
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F. J. Villacorta, H. N. Bordallo and M. Arai Quantum Beam Sci. 5, 2 (2021).

ESS bilbao

CONCLUSIONS

- ESS Bilbao is successfully delivering the Spanish In-Kind contribution to ESS (European Spallation Source, in Lund)
- We are as well starting other International Collaborations leveraging the know-how and capabilities obtained through the contribution to ESS
- ESS Bilbao, together with the user´s community and the industry, is working in the development of the ARGITU project, a HICANs that will foster R&D ecosystem in Euskadi and Beyond
- ARGITU is aligned with the local (Basque) R+D strategy and is part of the ELENA Association, whose members are actively promoting the important role that these infrastructures could play in sustaining the European neutron science ecosystem, as highlighted by LENS Vision Landscape document.

ESS BILBAO – Further information