EUROPEAN SPALLATION SOURCE

The ESS Project

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Group Leader Linac

www.europeanspallationsource.se
4 July 2016

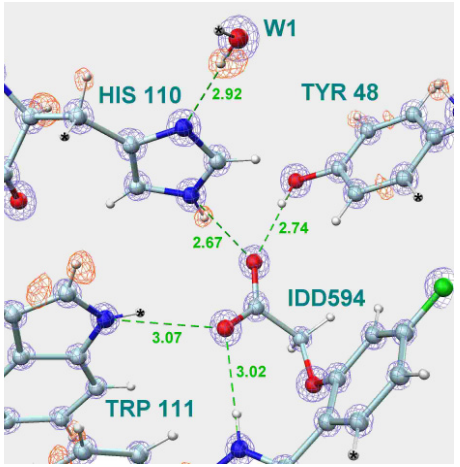
Reasons for Using Neutrons

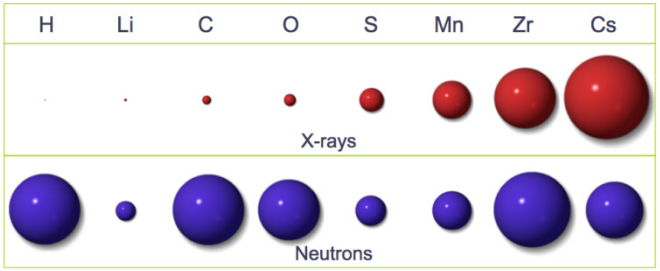
Charge neutral: Deeply penetrating, probe bulk of materials, even inside cryostats, magnets,...

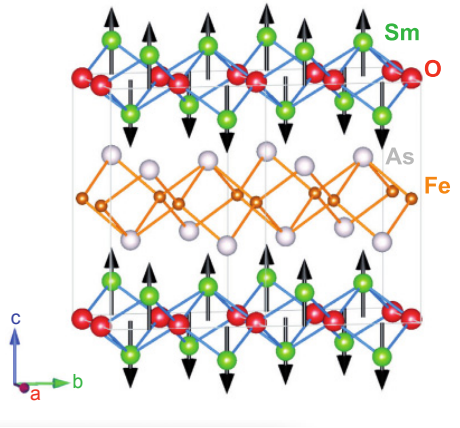
Nuclear interaction: Scattering cross section depends on isotope, not Z, and is high for hydrogen. Sensitivity to light elements.

Mass: Thermal neutrons have wavelengths similar to interatomic distances and energies of elementary excitations of solids.

Spin: Makes neutrons a probe for magnetic structure.







ESS Project

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International Collaboration

Sweden and Denmark:
47.5% Construction
15% Operations
In-kind deliverables ~3%
Cash investment ~97%

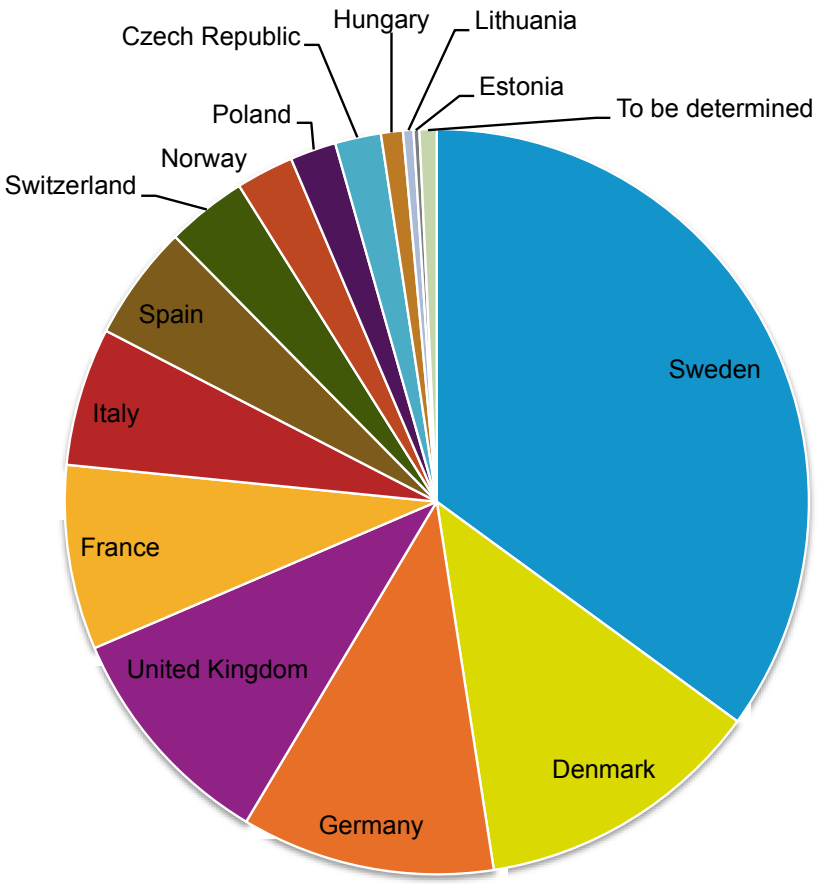
Partner Countries:
52.5% Construction
85% Operations
In-kind deliverables ~70%
Cash investment ~30%

New Partners:
Discussions in progress

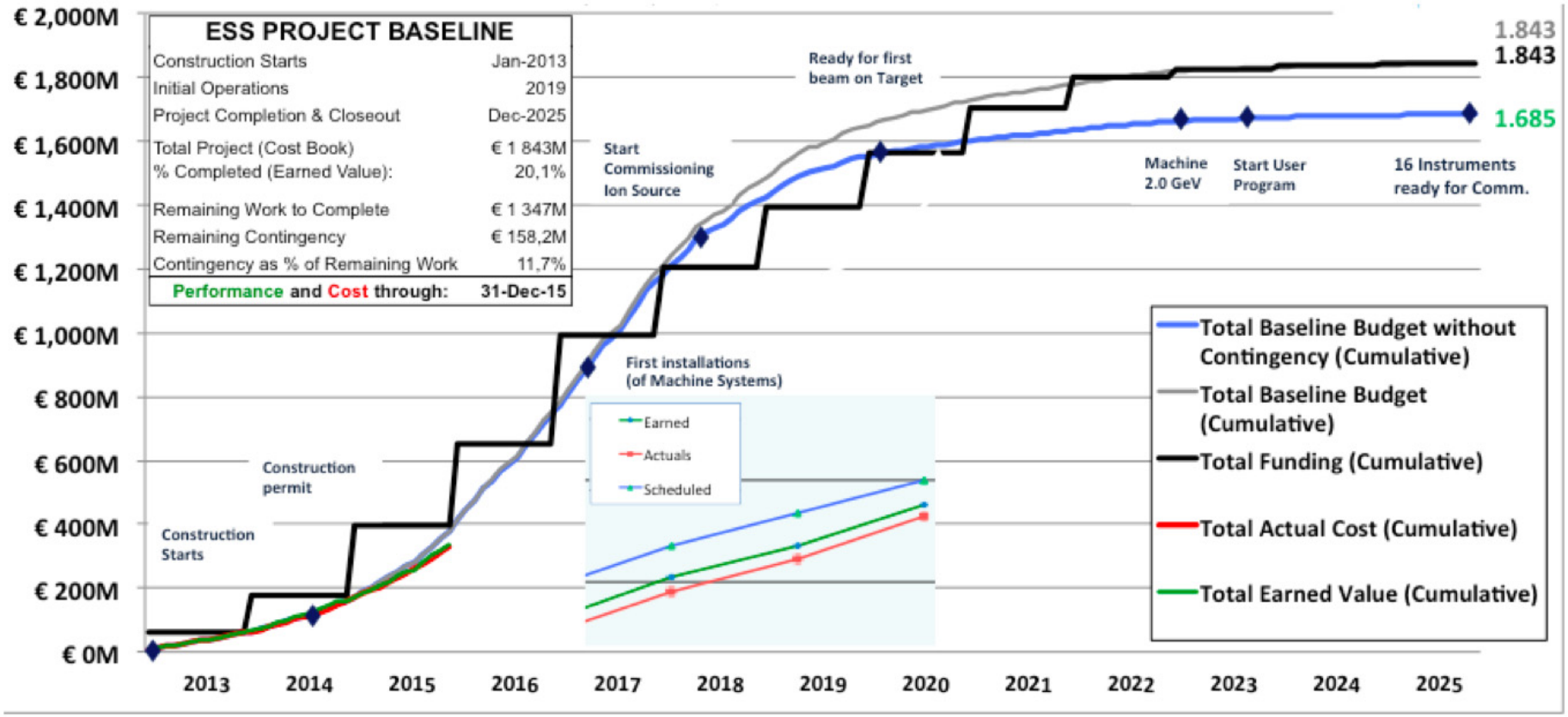
Construction Funding Status

Country	Membership	Percentage
Sweden	Member	35.0
Denmark*	Member	12.5
Germany*	Member	11.0
United Kingdom	Member	10.0
France	Member	8.0
Italy	Member	6.0
Spain*	Observer	5.0
Switzerland	Member	3.5
Norway	Member	2.5
Poland	Member	2.0
Czech Republic	Member	2.0
Hungary	Member	0.95
Lithuania	Future member	0.45
Estonia	Member	0.25
Sum		**99.15**
Belgium	Observer	tbd
Netherlands	Observer	tbd
Greece	Future observer	tbd
Iceland		tbd
Latvia		tbd

Discussions ongoing with Portugal, Turkey, Finland
*) Including contributions to pre-construction

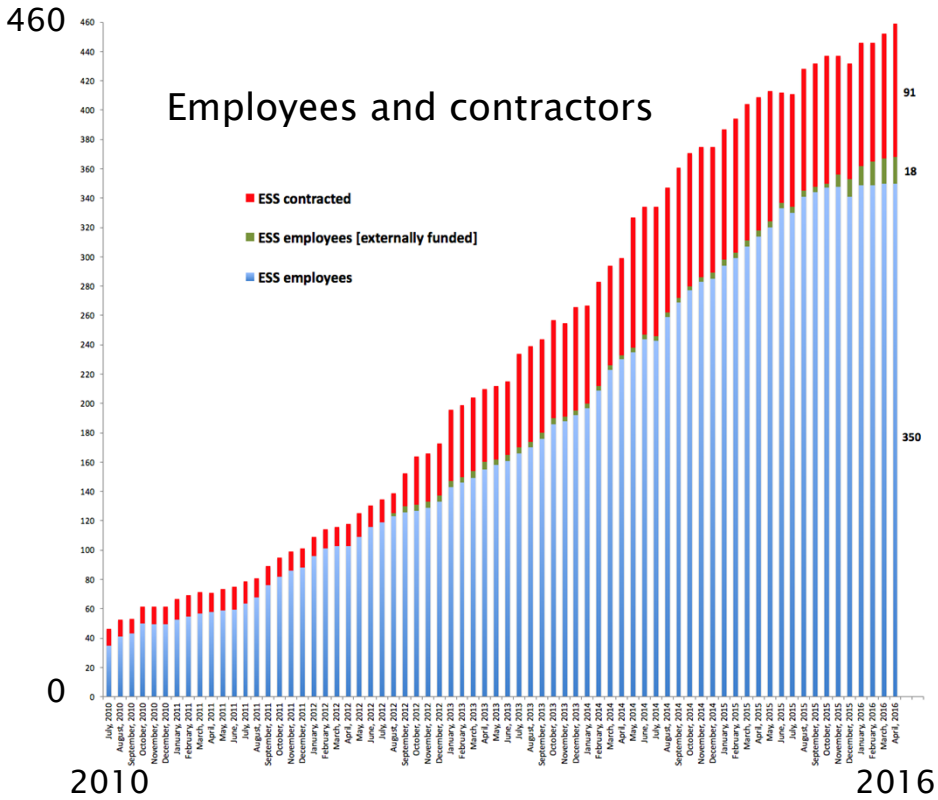


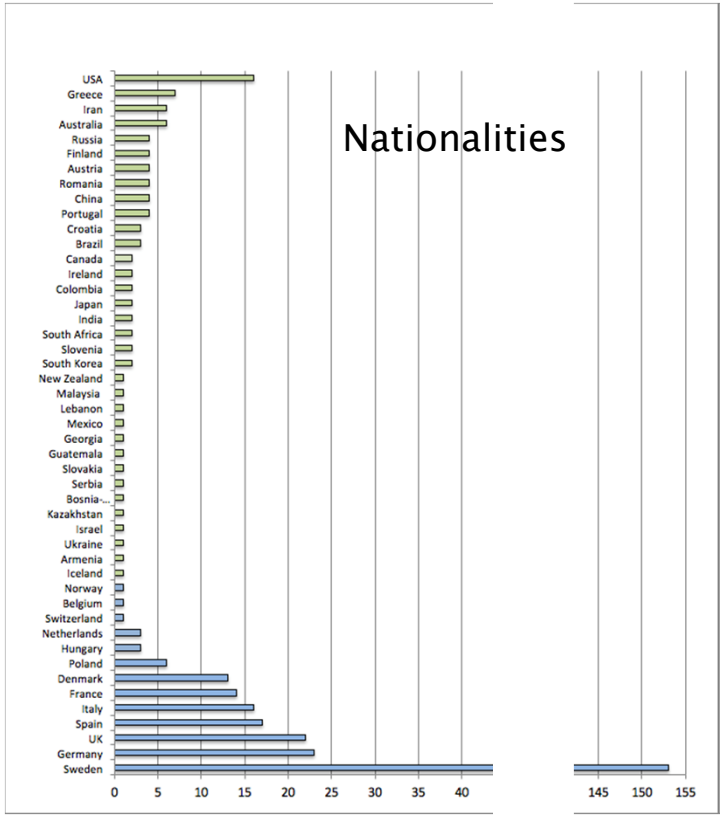
Construction Funding and Budget Profile



Staffing

Young and multi-cultural, 370 employees from 47 countries (04/2016)





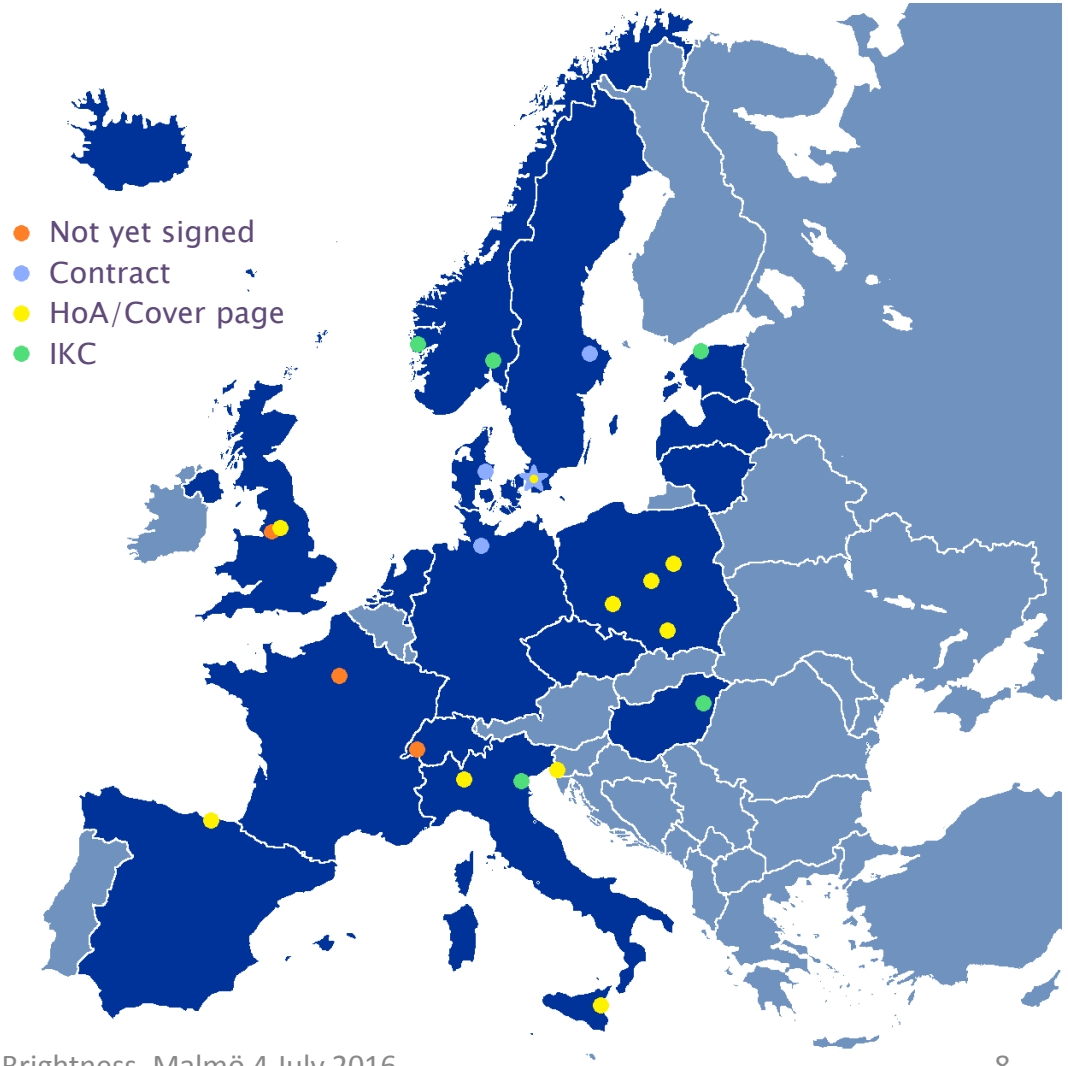
Partner Institutions for In-Kind

In-kind (main contributions)

ATOMKI (RF-LPS)
CEA (RFQ, SRF, Diagn)
CNRS (SRF, Cryo distrib)
Daresbury Lab (SRF, Vacuum)
Elettra (RF, Magn, PS, Diagn)
EPFL (Modulators)
ESS-Bilbao (MEBT, RF)
Huddersfield Univ (RF distrib)
IFJ PAN (Installations)
INFN Catania (Source, LEBT)
INFN Legnaro (DTL)
INFN Milan (SRF)
Lodz UT (LLRF)
NCBJ (LLRF, gamma blockers)
Tallinn UT (RF)
Univ Bergen (Seconded staff)
Univ Oslo (Diagn)
Warsaw UT (LLRF)
Wroclaw UT (Cryo distrib)

Paid contracts

Aarhus Univ (Beam delivery)
DESY (Diagn)
Lund Univ (LLRF, RF)
Uppsala Univ (Tests)



Linac Design Principles

Design goals:

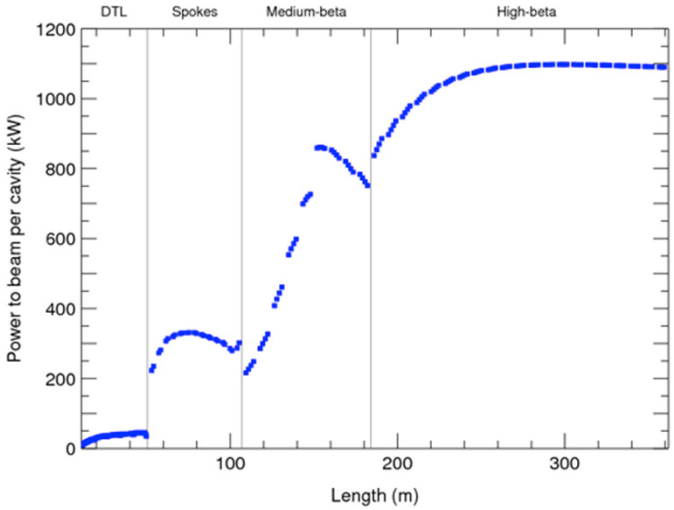
- Deliver as much power as possible to the beam as cheaply as possible
- Ensure small losses and high reliability

Beam physics rules-of-thumb:

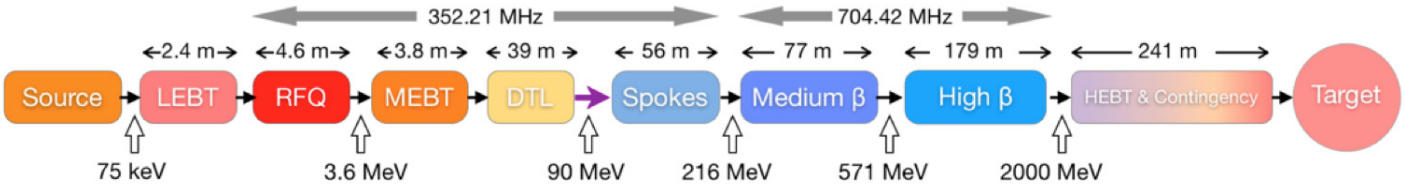
- Phase advance in each plane $< 90°$
- Smooth average phase advance
- Tune depression > 0.4

Limits to gradients and power couplers:

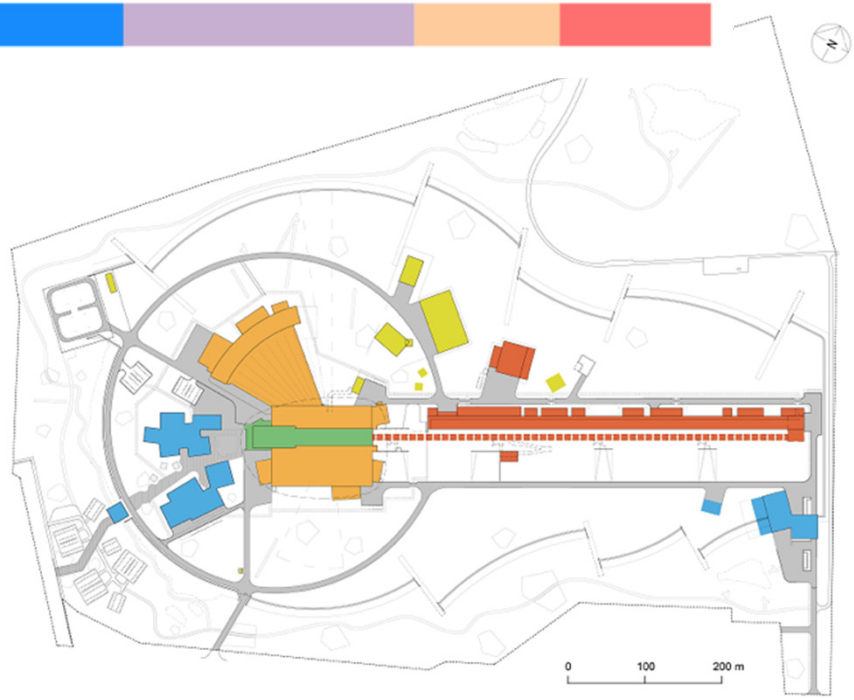
- Spoke cavities max gradient: 9 MV/m
- Elliptical max surface field: 45 MV/m
- Coupler max power: 1.1 MW



Linear Accelerator

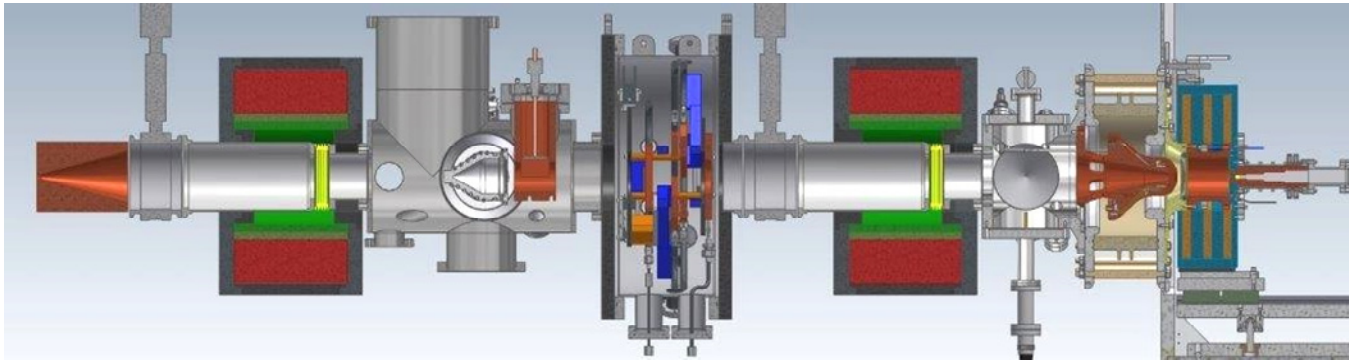


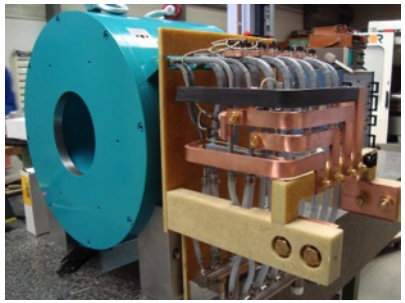
Particle species	p
Energy	2.0 GeV
Current	62.5 mA
Average power	5 MW
Peak power	125 MW
Pulse length	2.86 ms
Repetition rate	14 Hz
Operating time	5200 h/year
Reliability (all facility)	95%



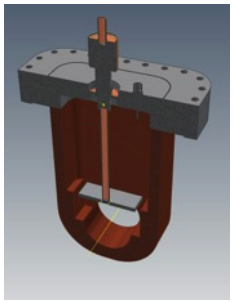
Ion Source and LEBT (INFN Catania)

Output energy 75 keV

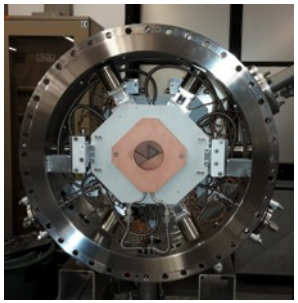




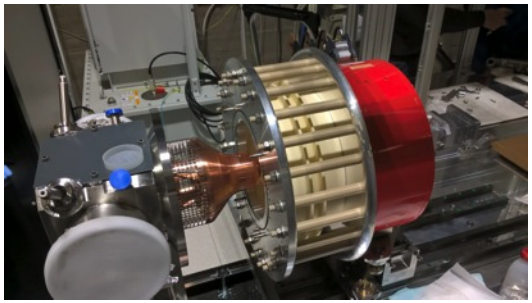
Solenoid



Chopper



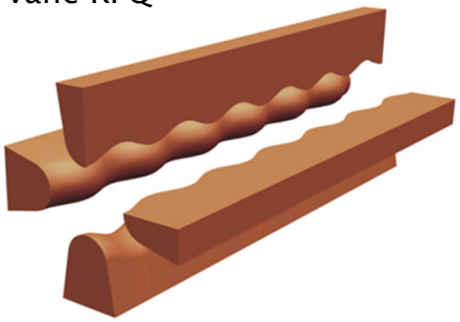
Iris



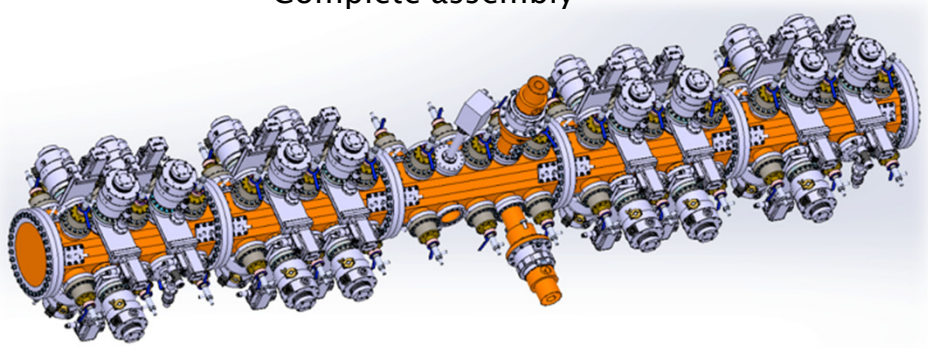
Microwave Discharge Ion Source

RFQ (CEA Saclay)

4-vane RFQ



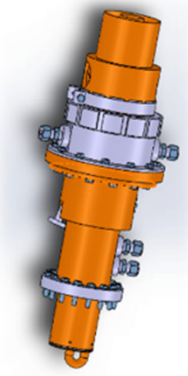
Complete assembly



Output energy 3.6 MeV

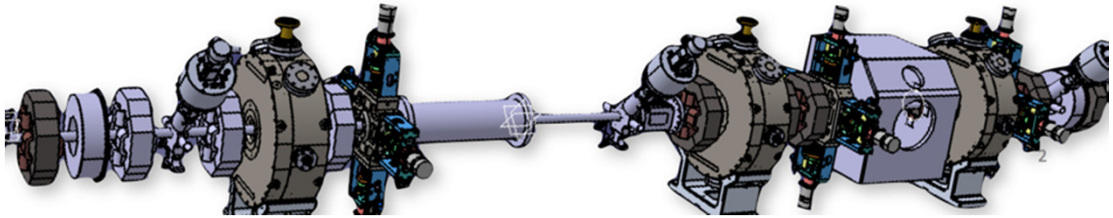
Copper OFE, ready for machining

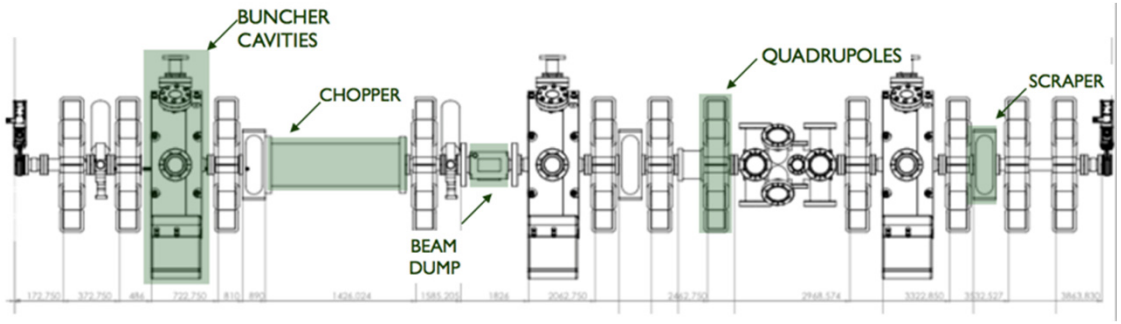
Tuner prototype



Power coupler

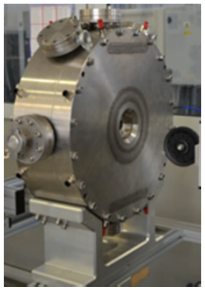
MEBT (ESS-Bilbao)



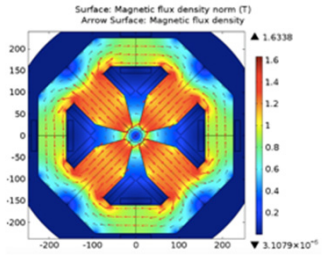


Many functions in 3.9 m:

- Beam shaping
- Chopping
- Collimation
- Instrumentation



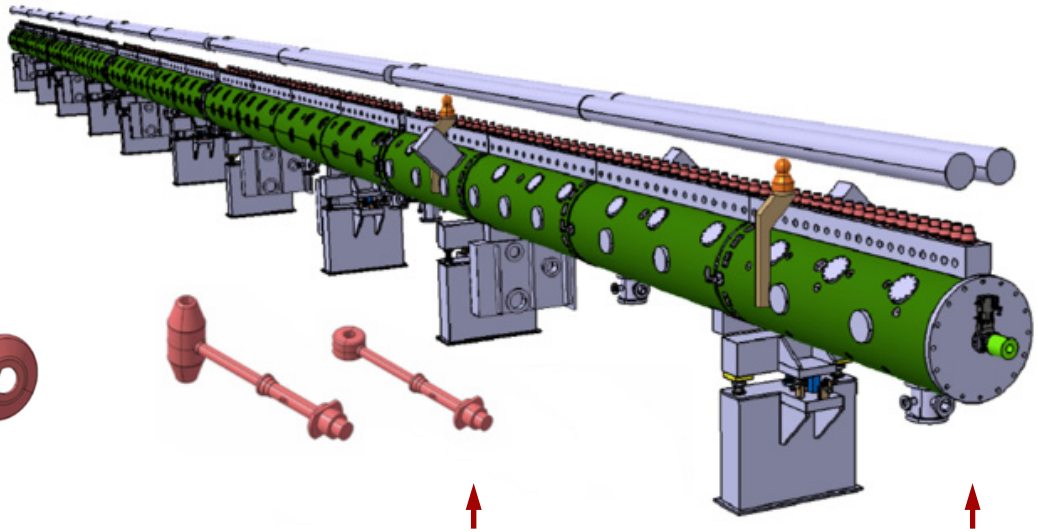
Prototype cavity



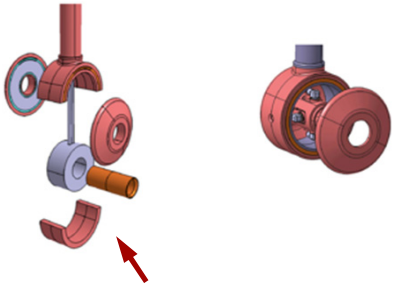
Quadrupole model

DTL (INFN Legnaro)

Tanks:	5
Sections/tank:	4
Length:	39 m
Weight:	34 tons

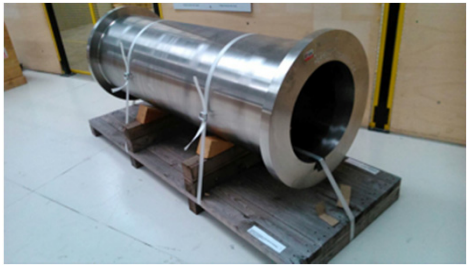


Output energy 90 MeV



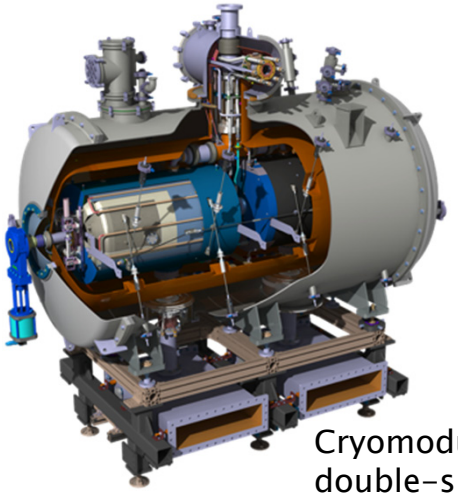
PMQ prototype

Stem & drift tube prototype



Section prototype

Spoke Cavities and Cryomodules (IPN Orsay)

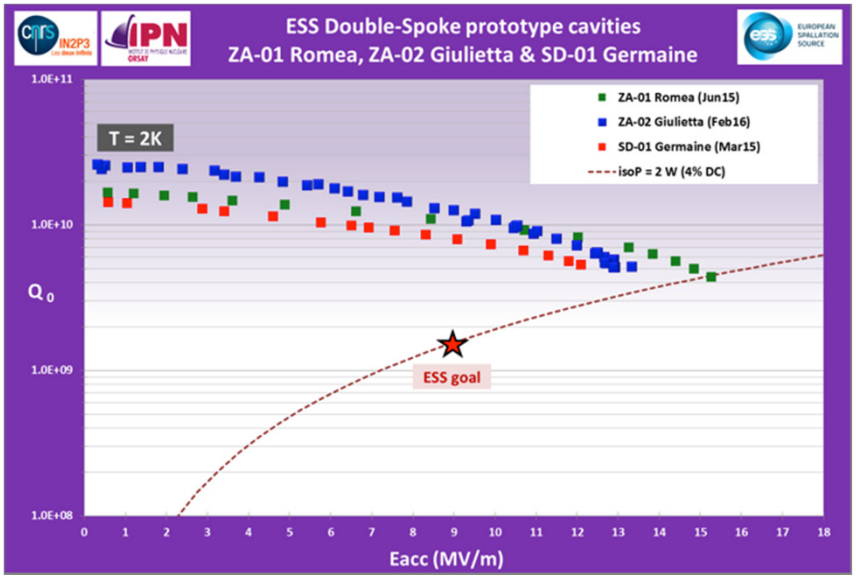


Output energy 216 MeV

Length 2.9 m

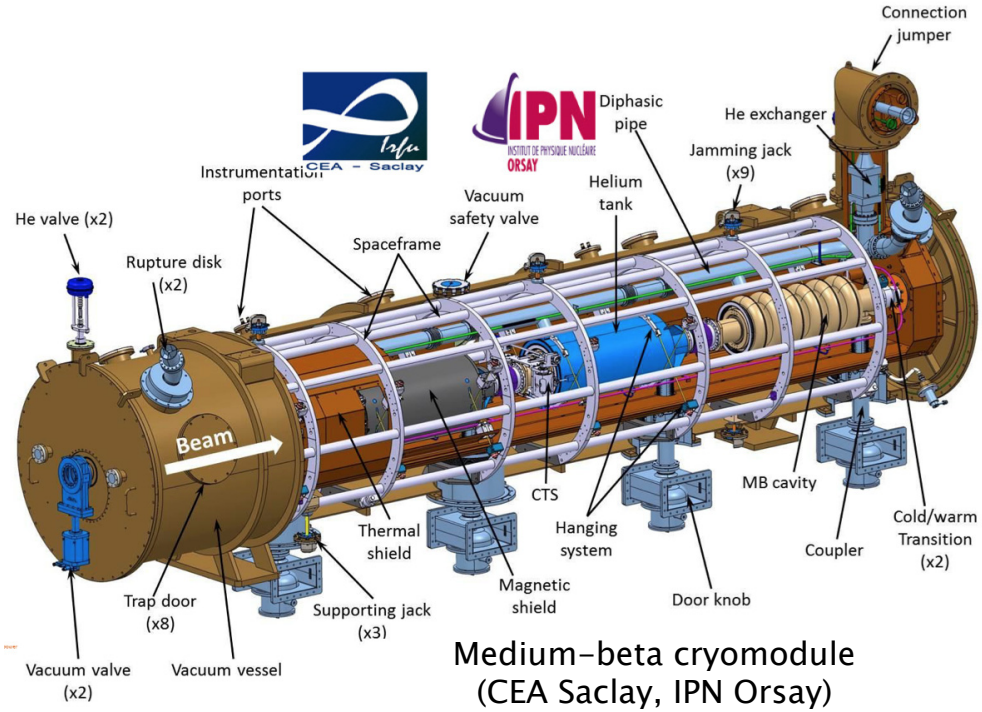
Cryomodule with two double-spoke cavities

Prototype cavity at IPNO set up for surface treatment



Tests of the three prototype cavities, exceeding ESS requirements in accelerating gradient and Q_0

Elliptical Cavities and Cryomodules (CEA Saclay)



Medium-beta cryomodule
(CEA Saclay, IPN Orsay)

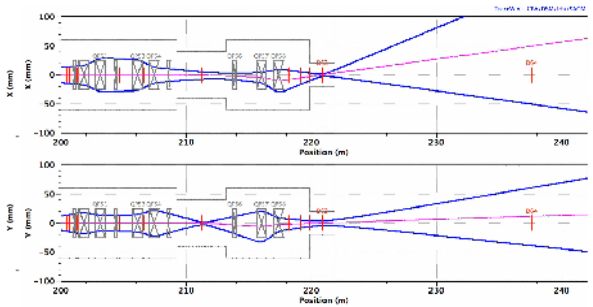
M-ECCTD vacuum tank

High-beta cavity prototype

Fabrication and testing of medium-beta (up to 561 MeV) and high-beta (up to 2 GeV) elliptical cavities will be in-kind contributions from INFN Milan and STFC Daresbury

Beam Delivery System (Aarhus Univ)

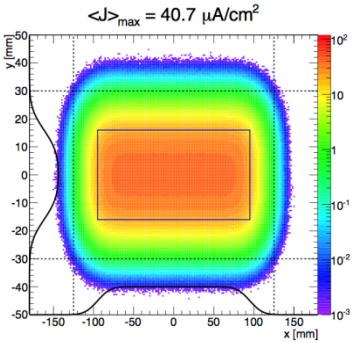
HEBT



Beam delivery system (Aarhus Univ.)

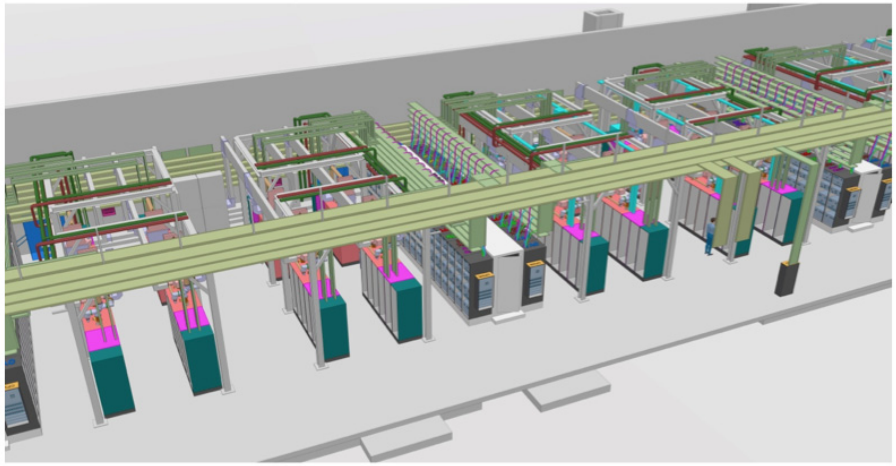
Target

Fast rastering magnets expands the beam onto the proton-beam window and the 250 mm × 60 mm beam entrance window on the target wheel

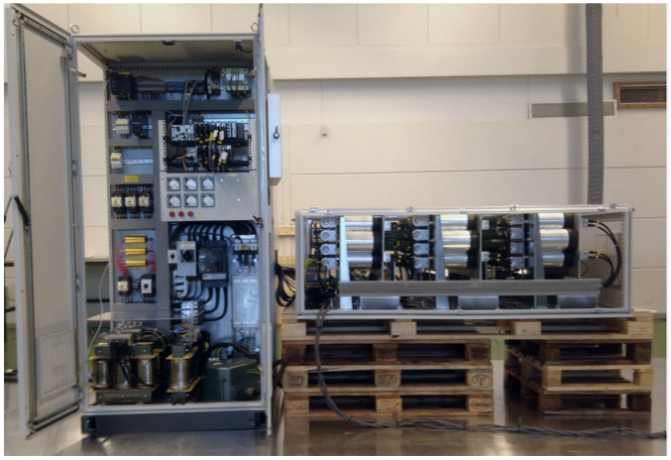


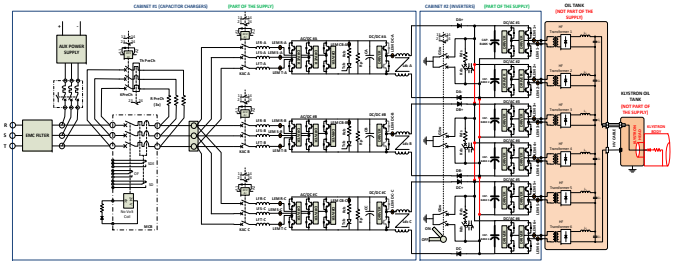
RF Sources

Main features:
- One RF power source (klystron, IOT, ...) per resonator
- Two klystrons per modulator for ellipticals
- Pulsed-cathode klystrons for RFQ, DTL
- Tetrode amplifiers for spokes (or solid state?)
- Klystrons for med-beta ellipticals, backup for high-betas
- Developments with industry for high-power IOTs
- LLRF, RF distribution, energy recovery,...



Part of spoke section of RF gallery (~10% of total gallery)





Development of novel high-power long-pulse modulators taking place at ESS

Multi-Beam IOTs

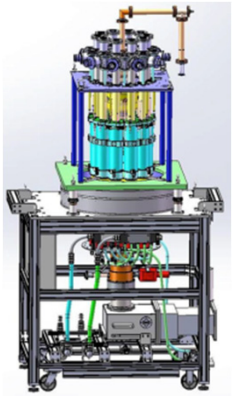
Contracts placed for two IOT technology demonstrators (Thales/CPI and L3)
Thales/CPI construction started
- Tube delivery expected November 2016
- FAT/SAT expected End of January 2017

L3 IOT already under test in the factory
- 1.2 MW achieved
- Efficiency > 60% from 600 kW to 1.2 MW

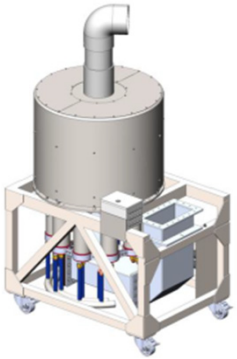
15 kW solid state driver delivered by Tomco
CERN test stand (for Thales/CPI) under construction
Discussions of further testing in Lund started
Pre-series for industrialisation under consideration

L3 tube after bake-out

Thales/CPI

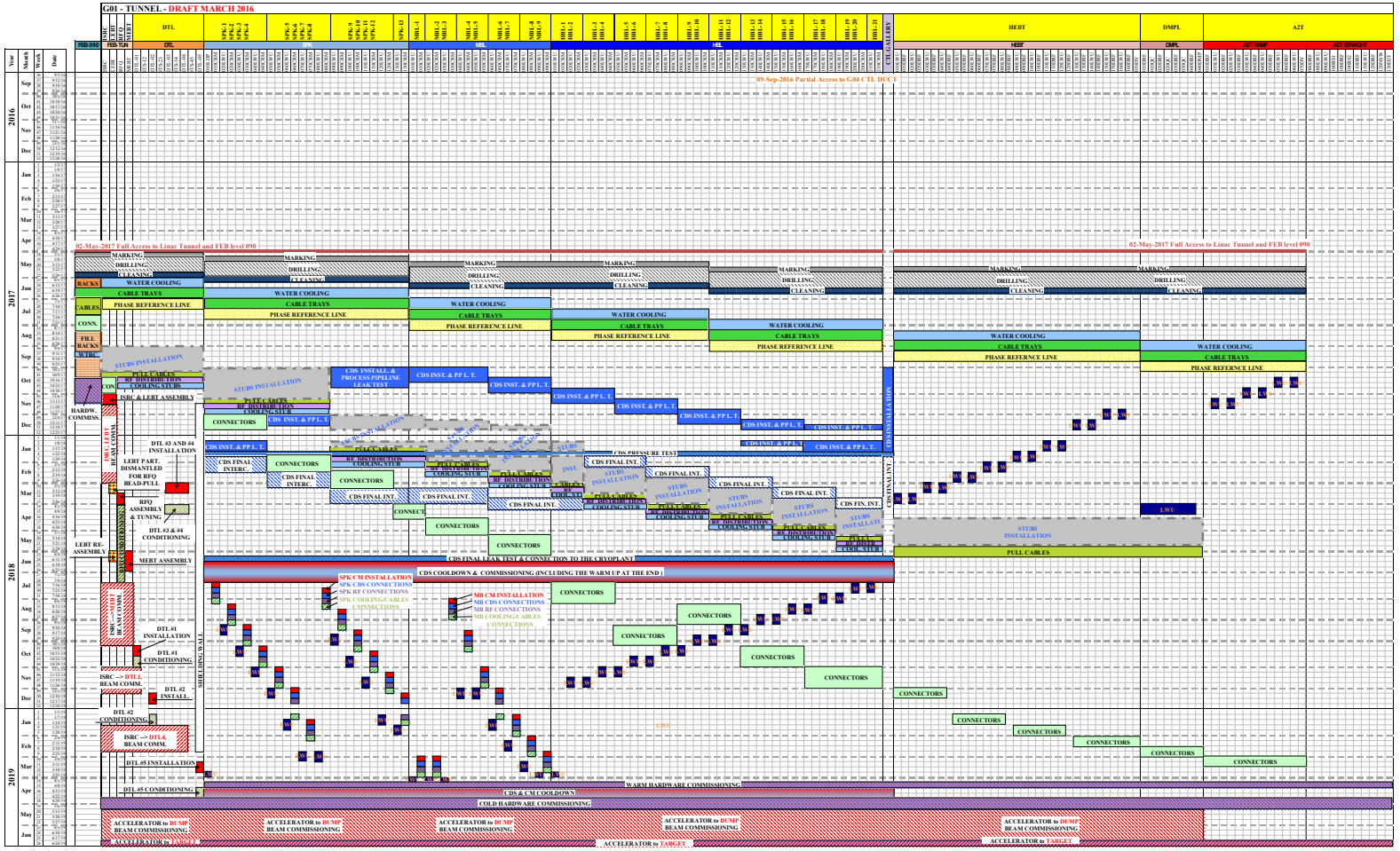


L3



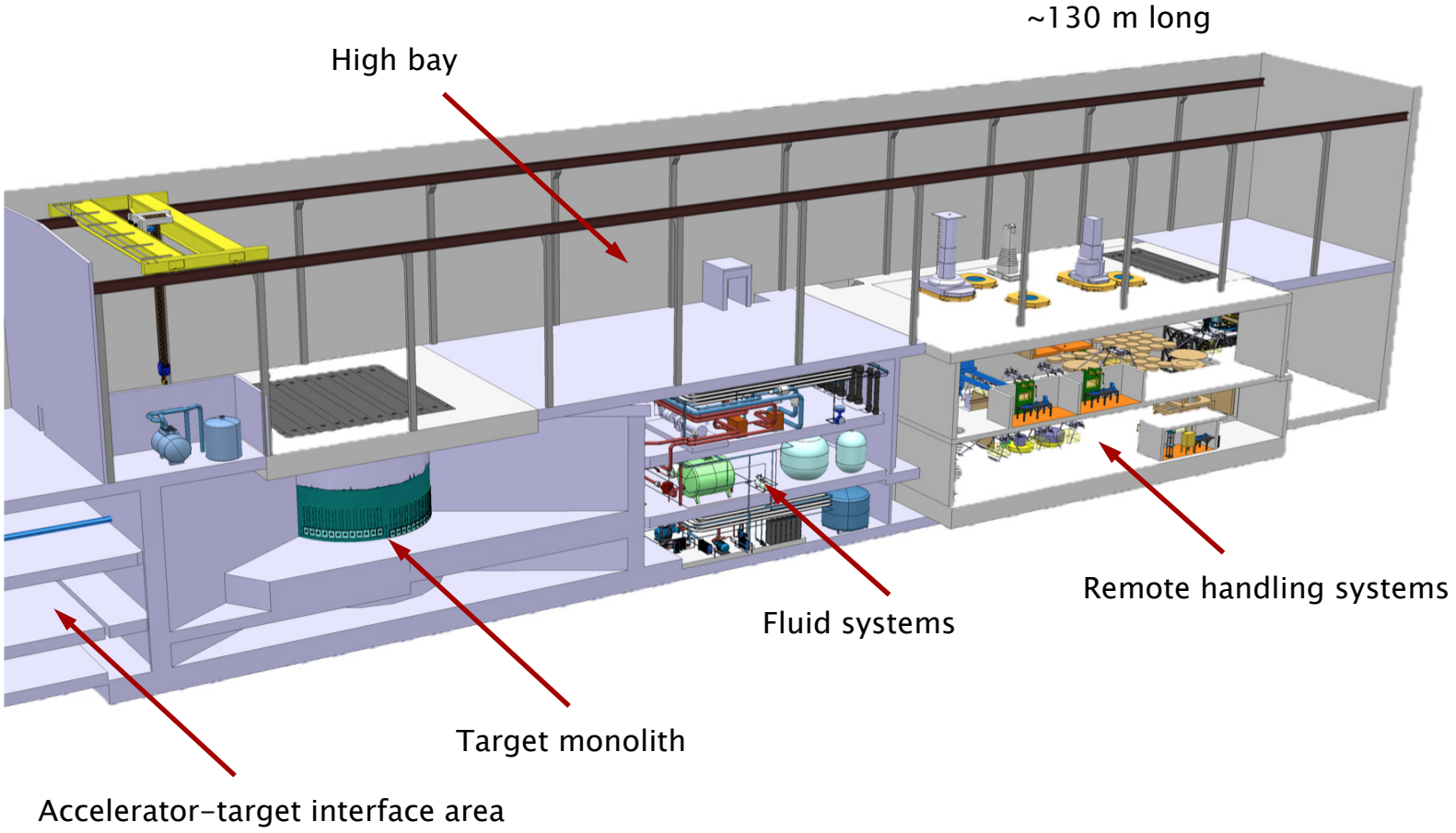
L-3 Communications Electron Devices' L6200 1.2 MW. 704 MHz Multi-Beam IOT for ESS

Installation Schedule, Tunnel

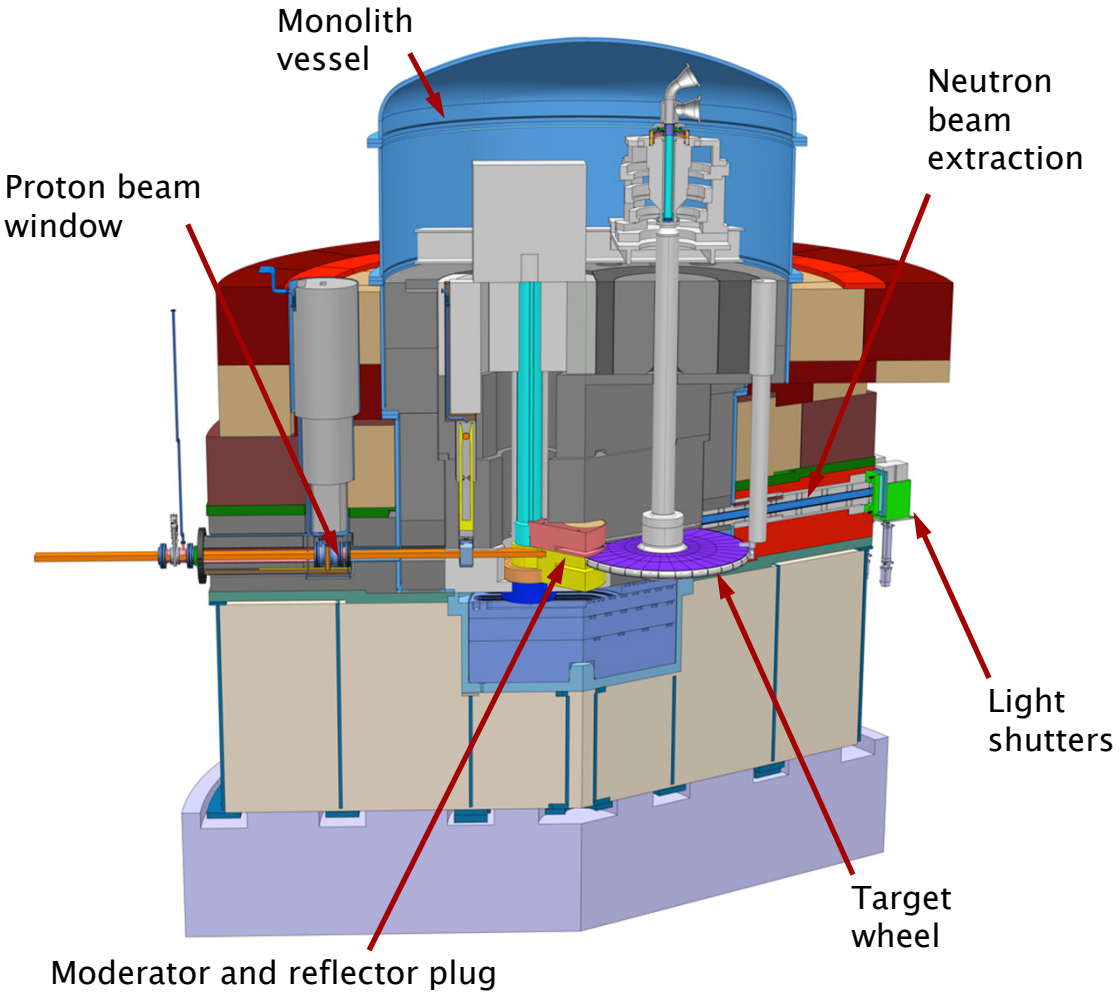


PREPARED BY L LARI and E. SARGSYAN
CHECKED BY WP LEADERS and GROUP LEADERS
APPROVED BY M. LINDROOS

Target Station

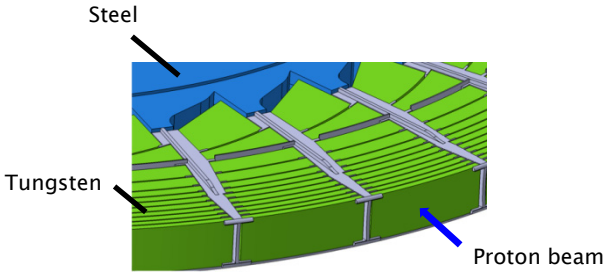


Target Monolith and Wheel



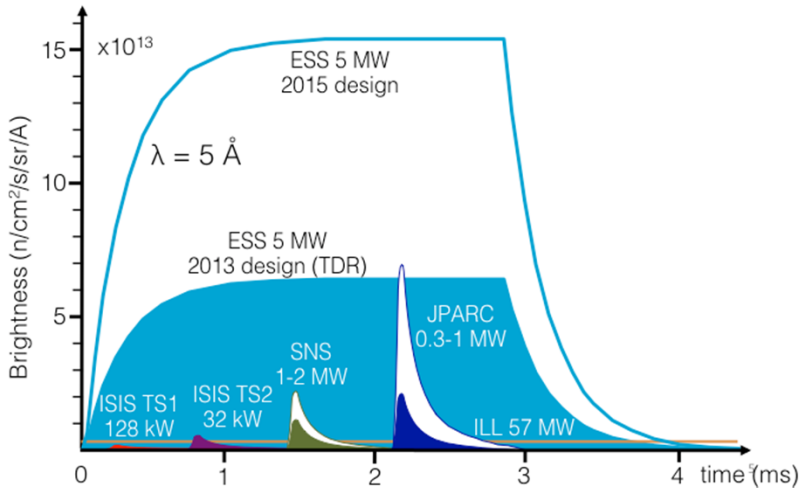
Features and requirements

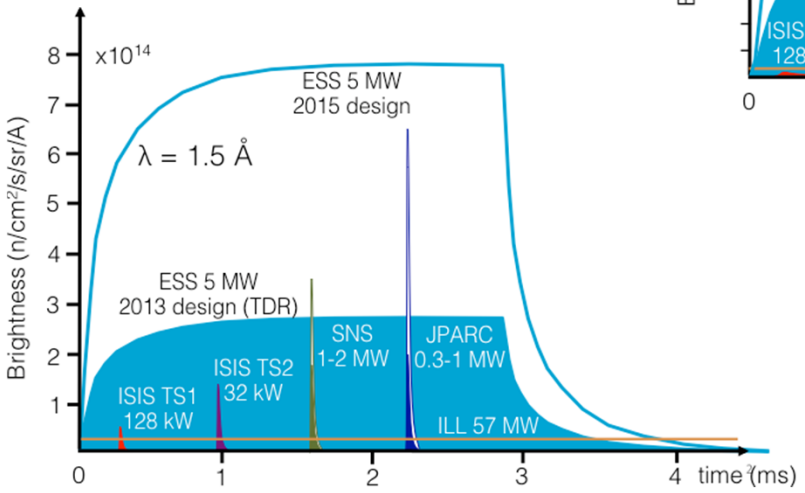
- Rotating target wheel
- 36 tungsten sectors
- 5 MW heat removal
- Helium gas cooling
- High brightness moderators
- Confinement and shielding



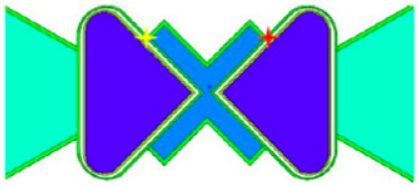
Improved Moderators

Optimized moderators provide more than 2-fold improvement in cold and thermal neutron source performance, compared to 2013 design



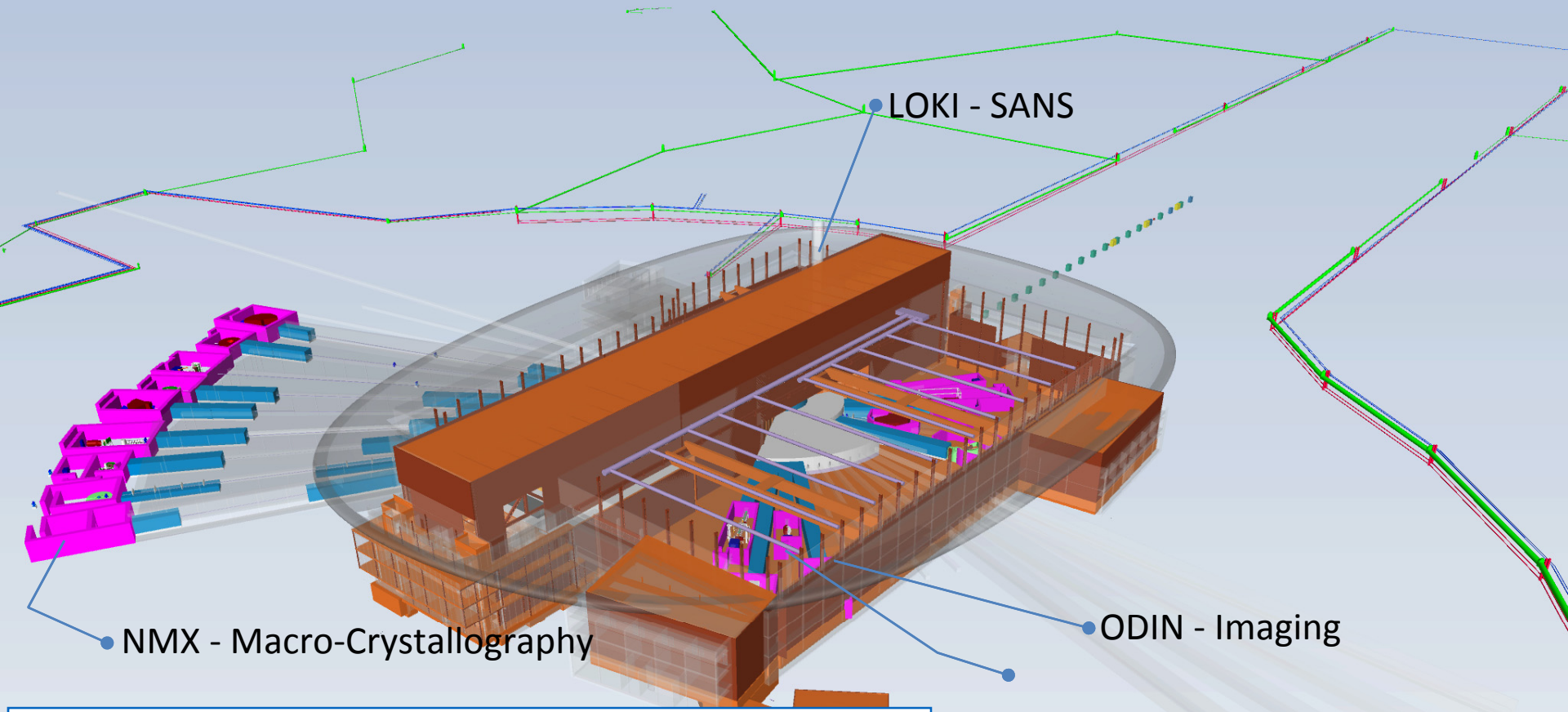


"Butterfly" moderator design



16-Instrument Suite Taking Shape

EUROPEAN SPALLATION SOURCE



2013 Round: Suggested 3 Instruments from 4 Proposals

Leading Institutions :

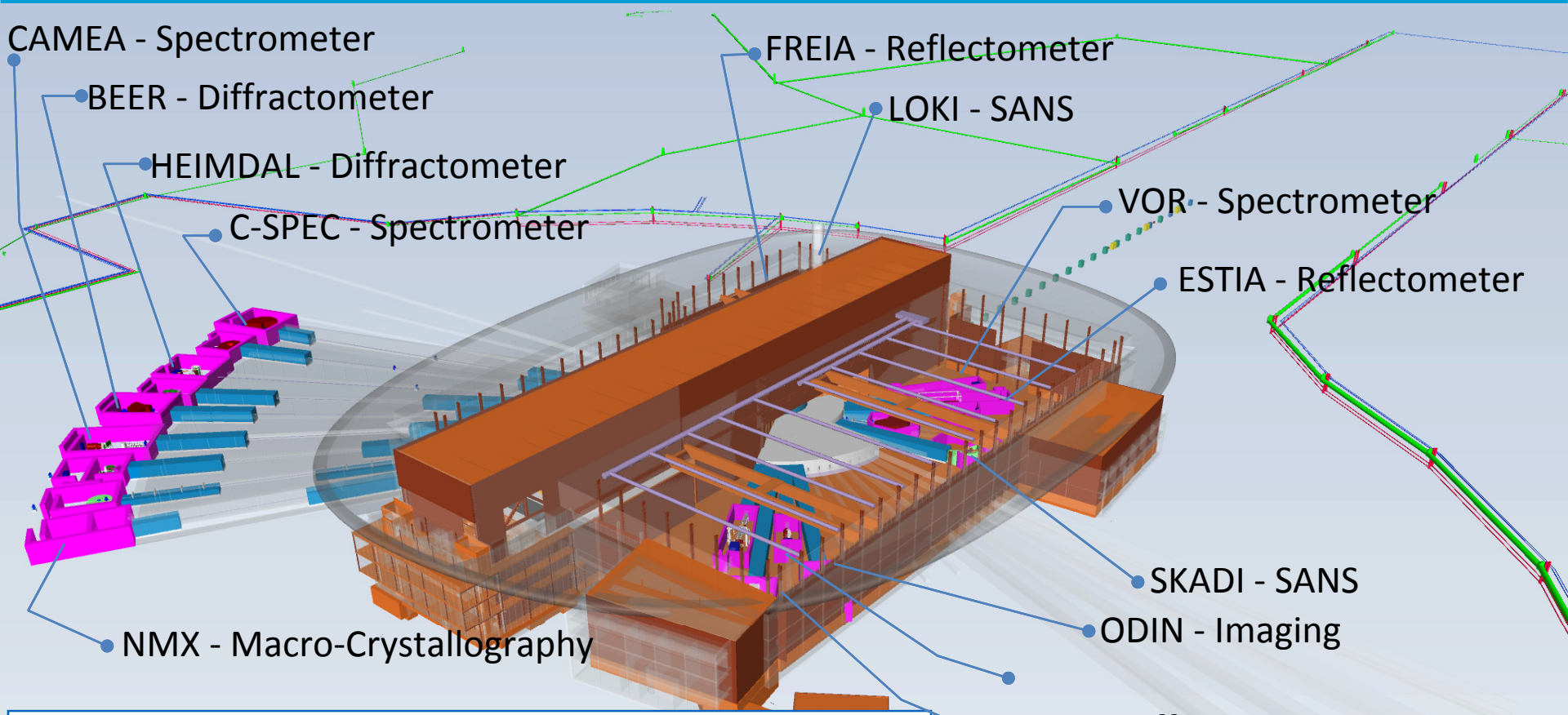
Helmholtz-Zentrum Geesthacht

ibs

AARHUS UNIVERSITY

PAUL SCHERRER INSTITUT PSI

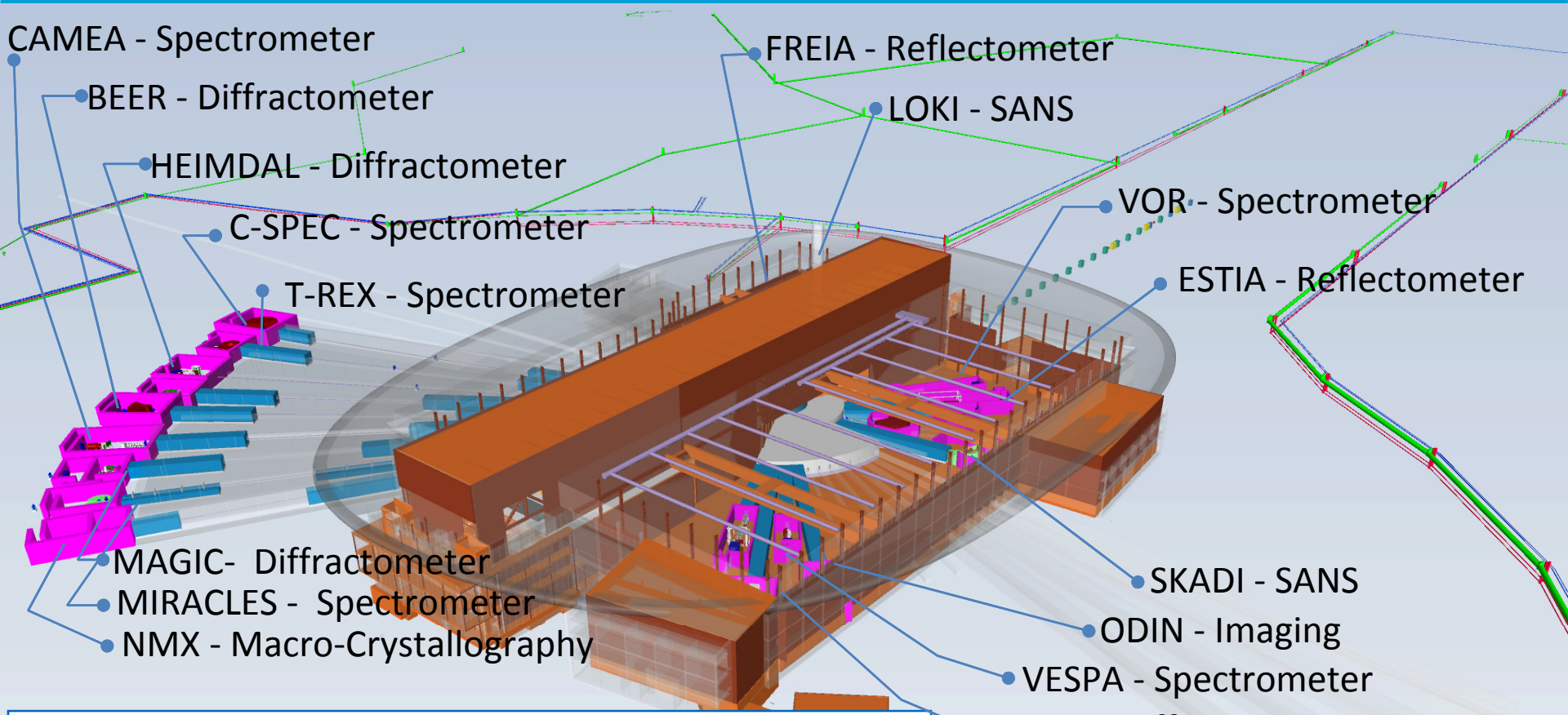
16-Instrument Suite Taking Shape



2013 Round: Suggested 3 Instruments from 4 Proposals
2014 Round: Suggested 9 Instruments from 16 Proposals

Leading Institutions :

16-Instrument Suite Taking Shape



2013 Round: Suggested 3 Instruments from 4 Proposals
2014 Round: Suggested 9 Instruments from 16 Proposals
2015 Round: Suggested 4 Instruments from 12 proposals

Leading Institutions : Helmholtz-Zentrum Geesthacht, ibs, AARHUS UNIVERSITY, PAUL SCHERRER INSTITUT PSI

Thank you!

EUROPEAN SPALLATION SOURCE