ESS PROGRESSING INTO CONSTRUCTION

Mats Lindroos
Head of accelerator at ESS
Adjungated Professor at Lund University, Physics
And the ESS accelerator collaboration

www.europeanspallationsource.se
13 May 2016

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Progress on civil construction
27 April 2016

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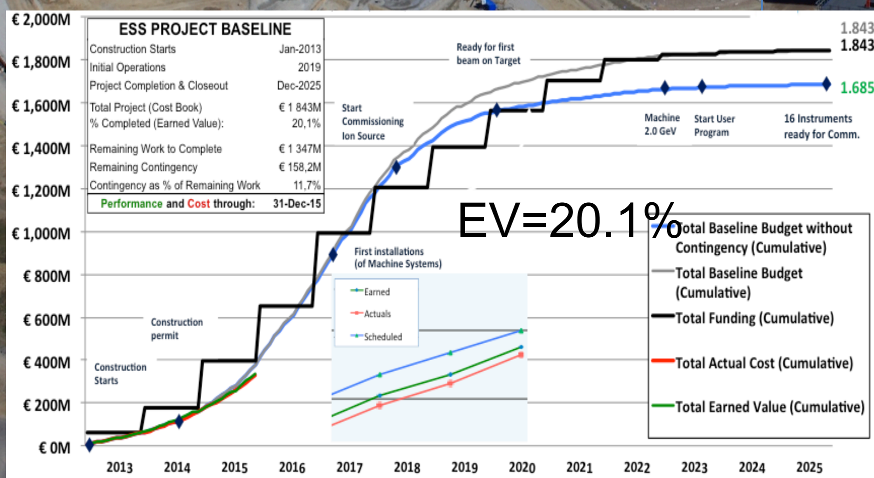
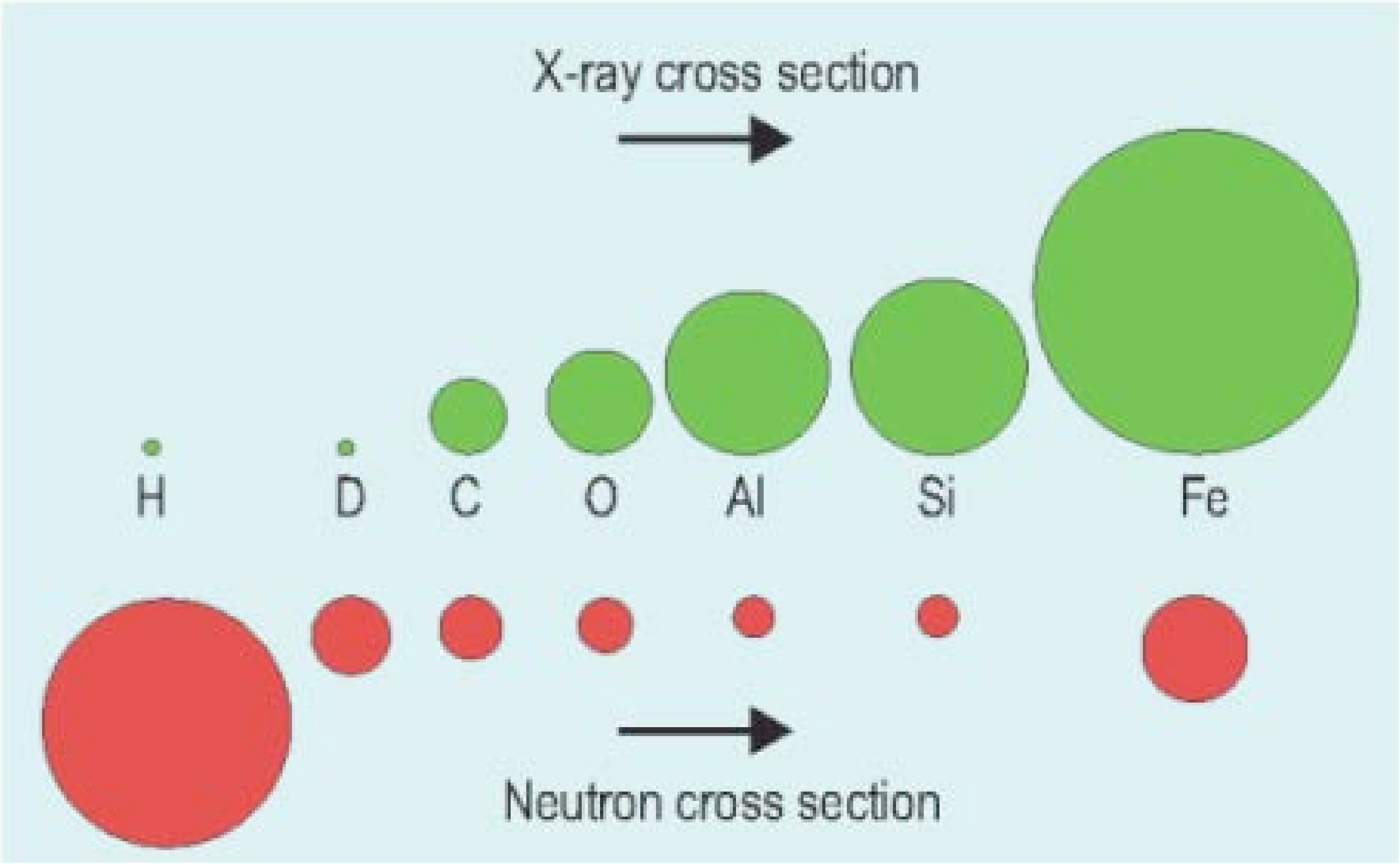


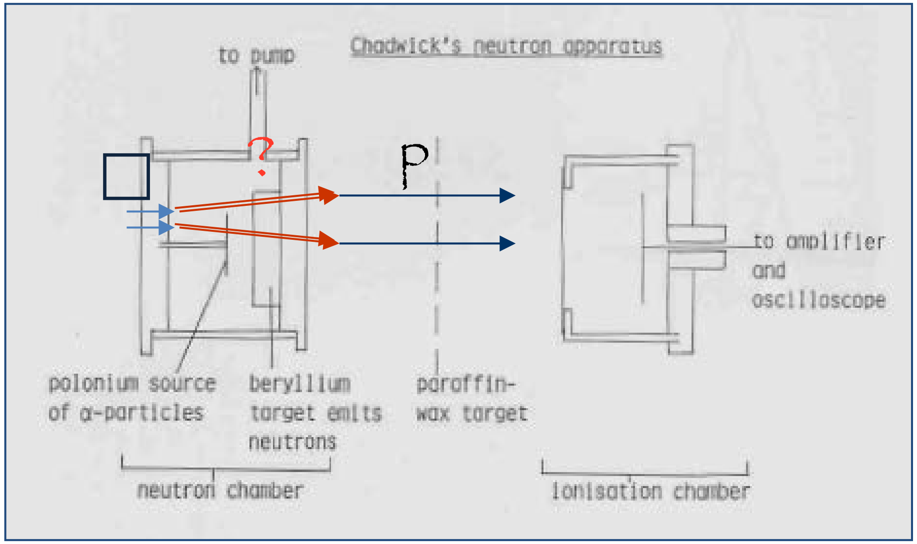
27 April 2016

Neutrons & x-rays: similar methods, sensitive to different elements.



Neutrons

Its discovery
James Chadwick
1932
(α,n) reaction



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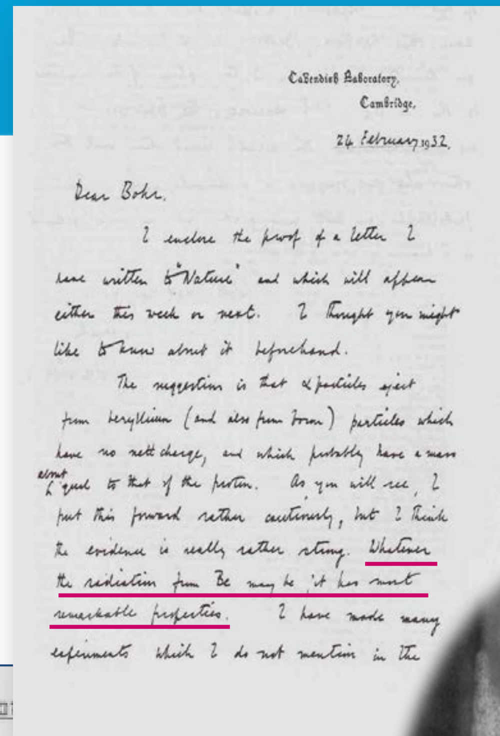
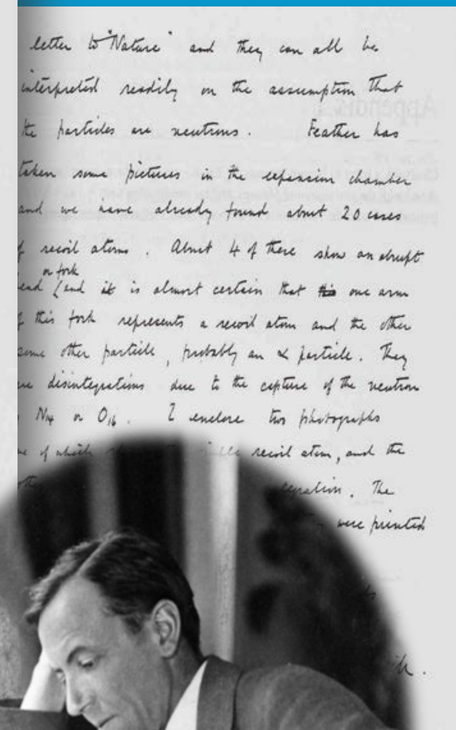

Cavendish Laboratory,
Cambridge.

24 February 1932.

Dear Bohr,

I enclose the proof of a letter I have written to 'Nature' and which will appear either this week or next. I thought you might like to know about it beforehand.

The suggestion is that α particles eject from beryllium (and also from boron) particles which have no nett charge, and which probably have a mass about equal to that of the proton. As you will see, I put this forward rather cautiously, but I think the evidence is really rather strong. Whatever the radiation from Be may be, it has most remarkable properties. I have made many experiments which I do not mention in the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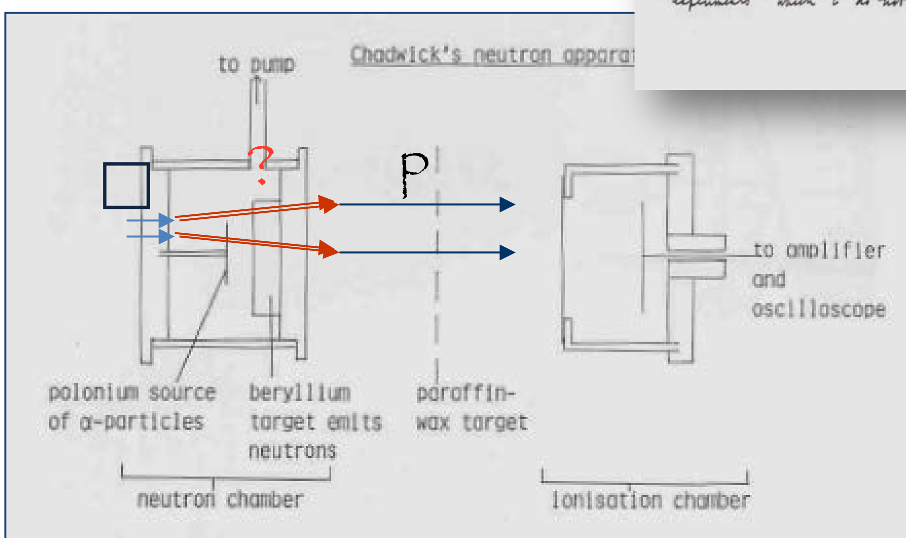

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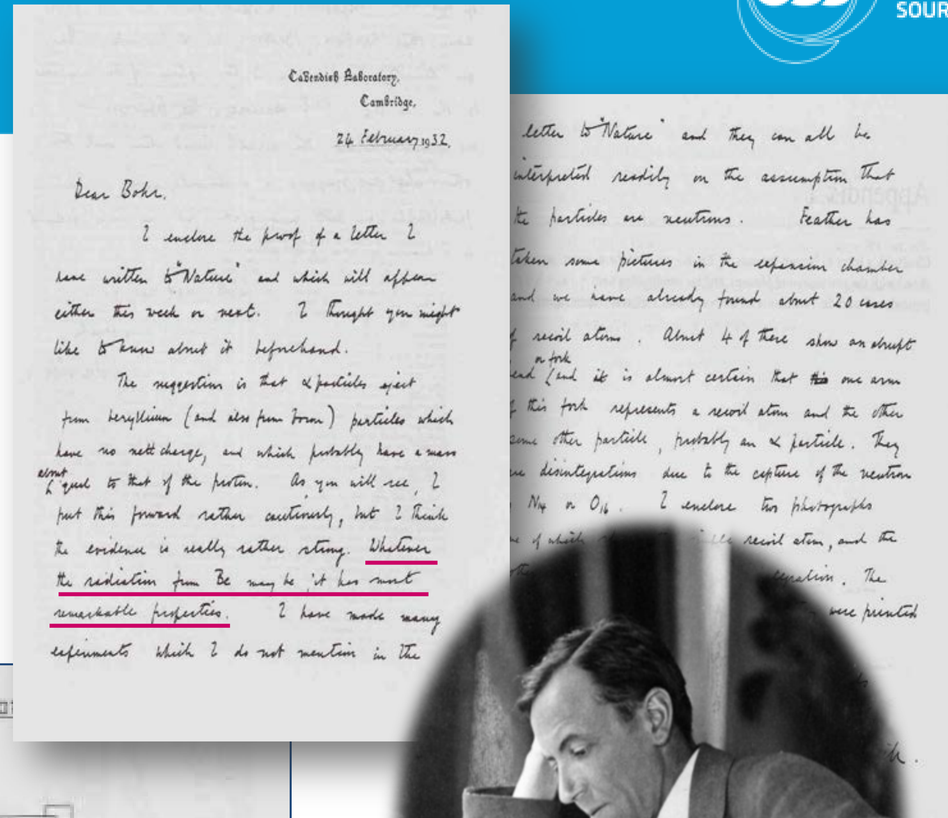

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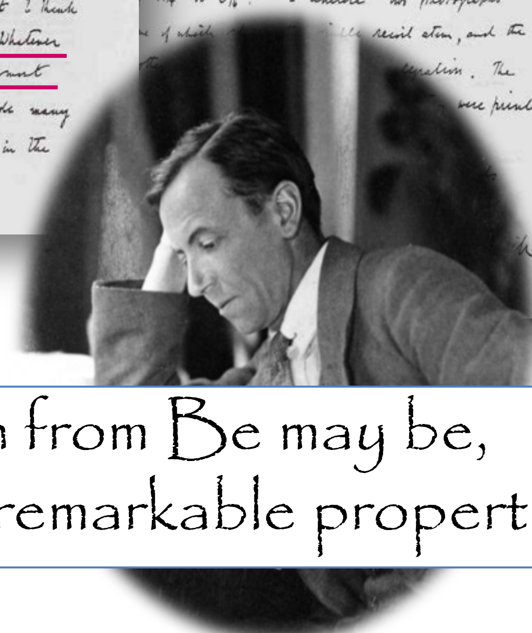
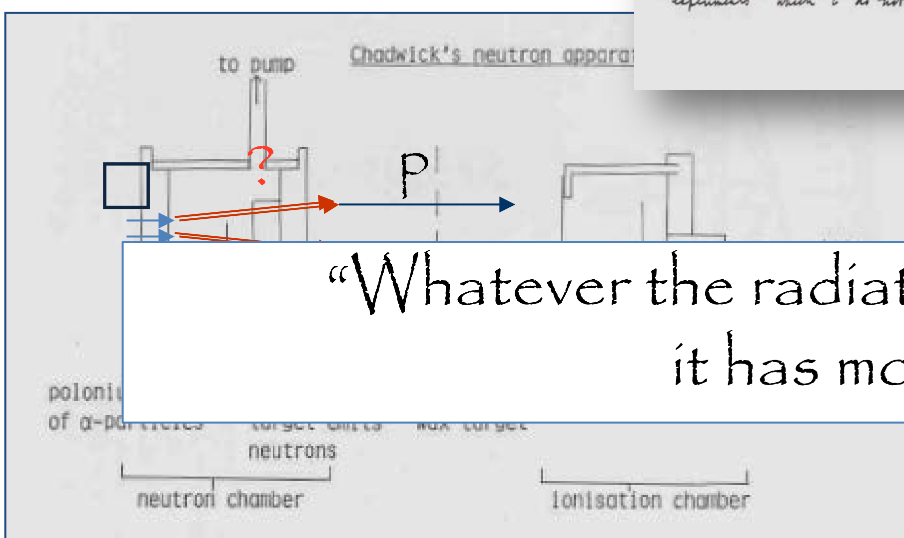
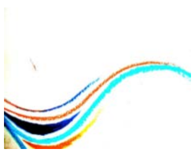
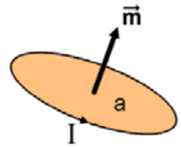
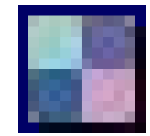




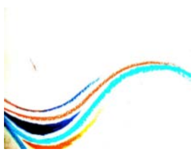
"Whatever the radiation from Be may be,
it has most remarkable properties"

Neutrons are beautiful!

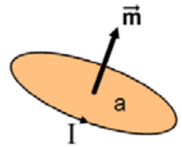
Wave	Magnetic moment	Particle	Neutral
			

Neutrons are beautiful!

Wave

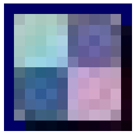


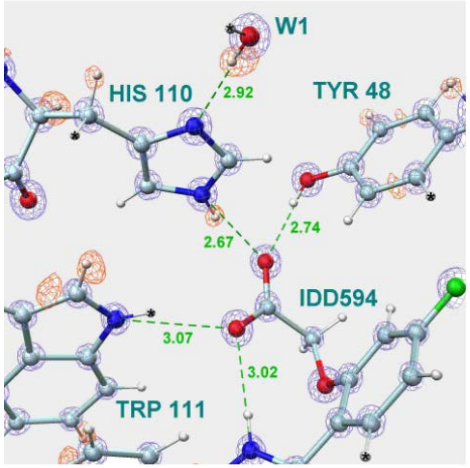
Magnetic moment



Particle

Neutral





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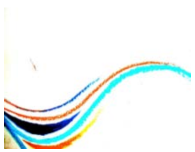
Wave



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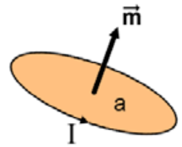

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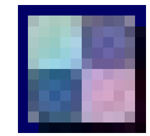

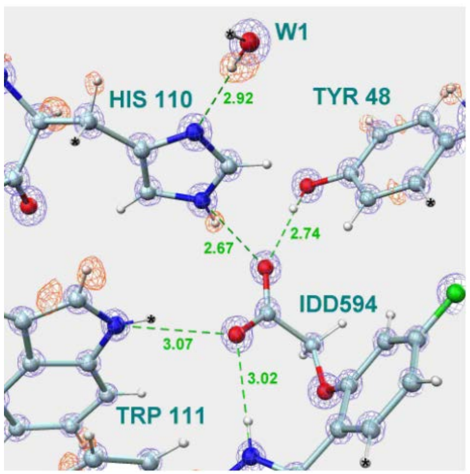

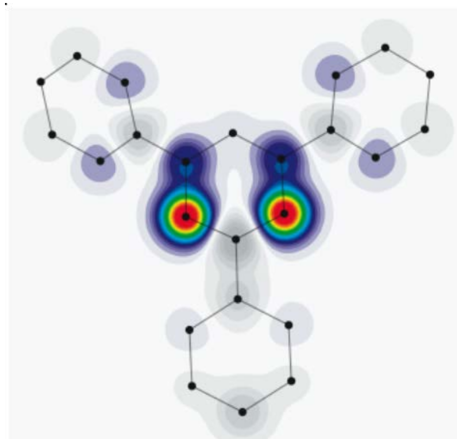

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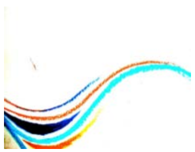

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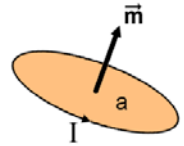

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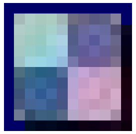

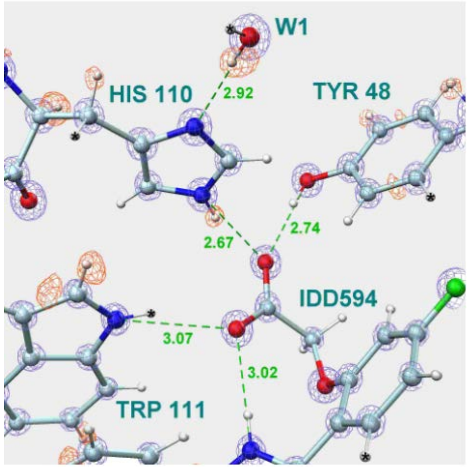

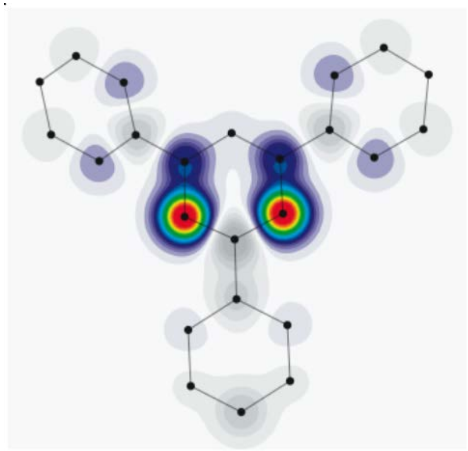

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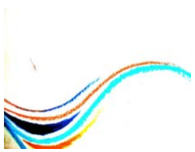

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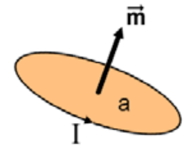

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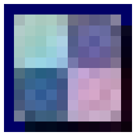


Diffractometers - Measure structures

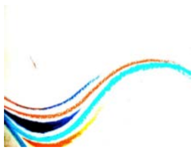
– Where atoms and molecules are

Spectrometers - Measure dynamics

– What atoms and molecules do

Neutrons are beautiful!

Wave



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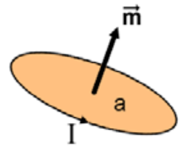

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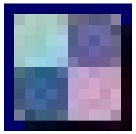

Diffractometers - Measure structures

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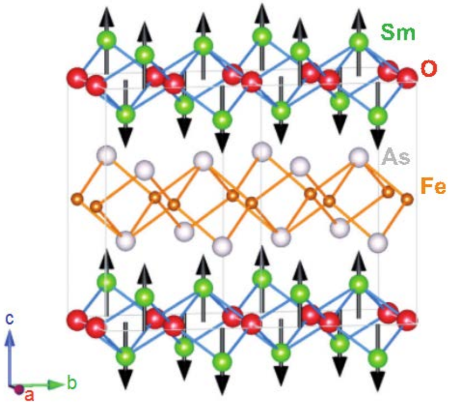

Spectrometers - Measure dynamics

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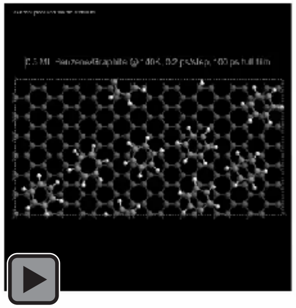

Some visions for neutron and light source science

- Higher (Room?) Temperature Super Conductors
- Hydrogen storage substrate
- Efficient membrane for fuel cells
- Flexible and highly efficient solar cells
- Understanding liquid membranes
- Nano scaled structures for controlled drug release
- Self healing materials – smart materials
- Spintronics - Spin-state as a storage of data (10^{23} gain in capacity)
- CO_2 sequestration
- Neutron electric dipole moment
- Neutron oscillations
- And much more…

Journey to deliver the world's leading facility for research using neutrons

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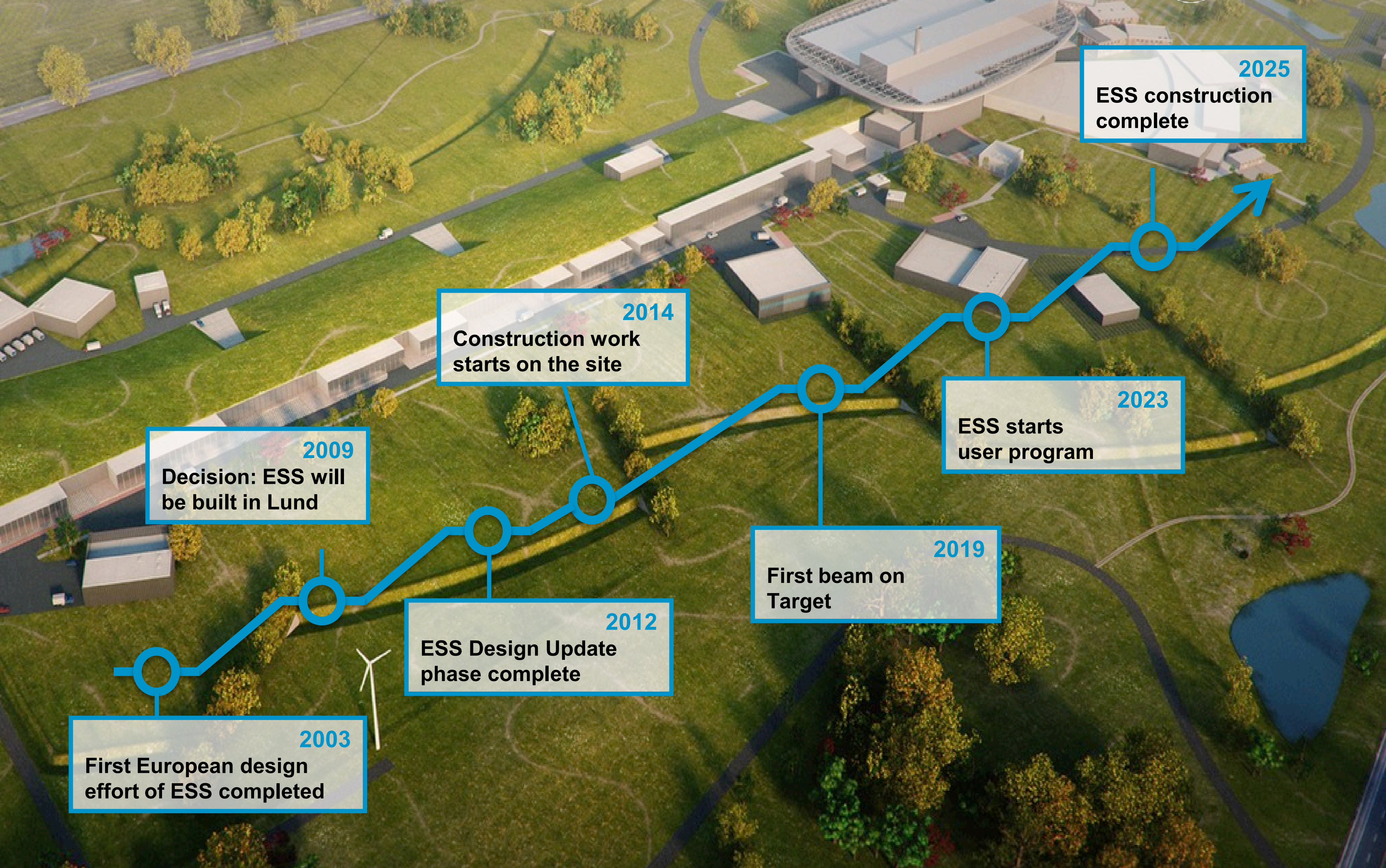


ESS design

EUROPEAN SPALLATION SOURCE

Total cost: 1843 MEuros $_{2013}$

ESS design

EUROPEAN SPALLATION SOURCE

ESS design

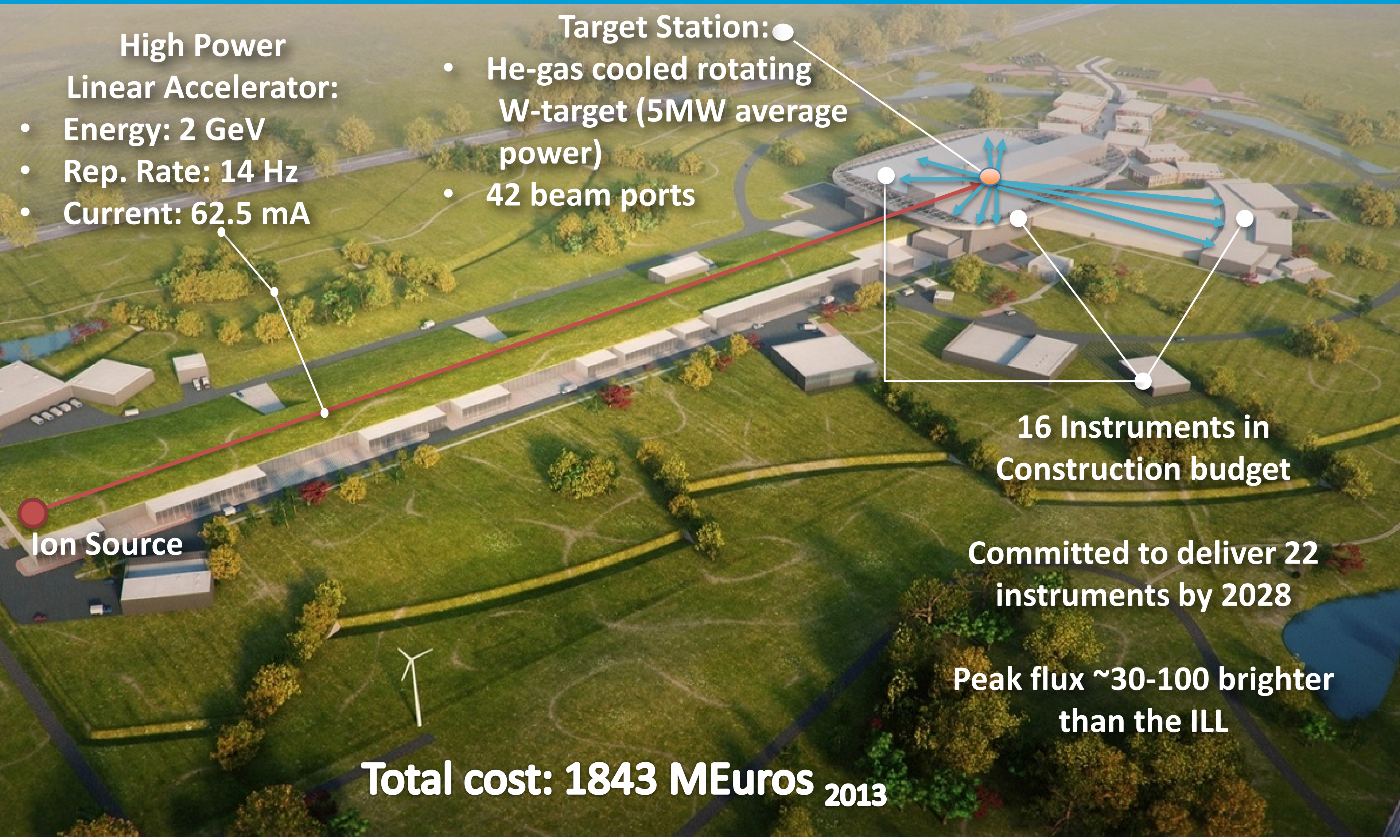
EUROPEAN SPALLATION SOURCE

ESS design

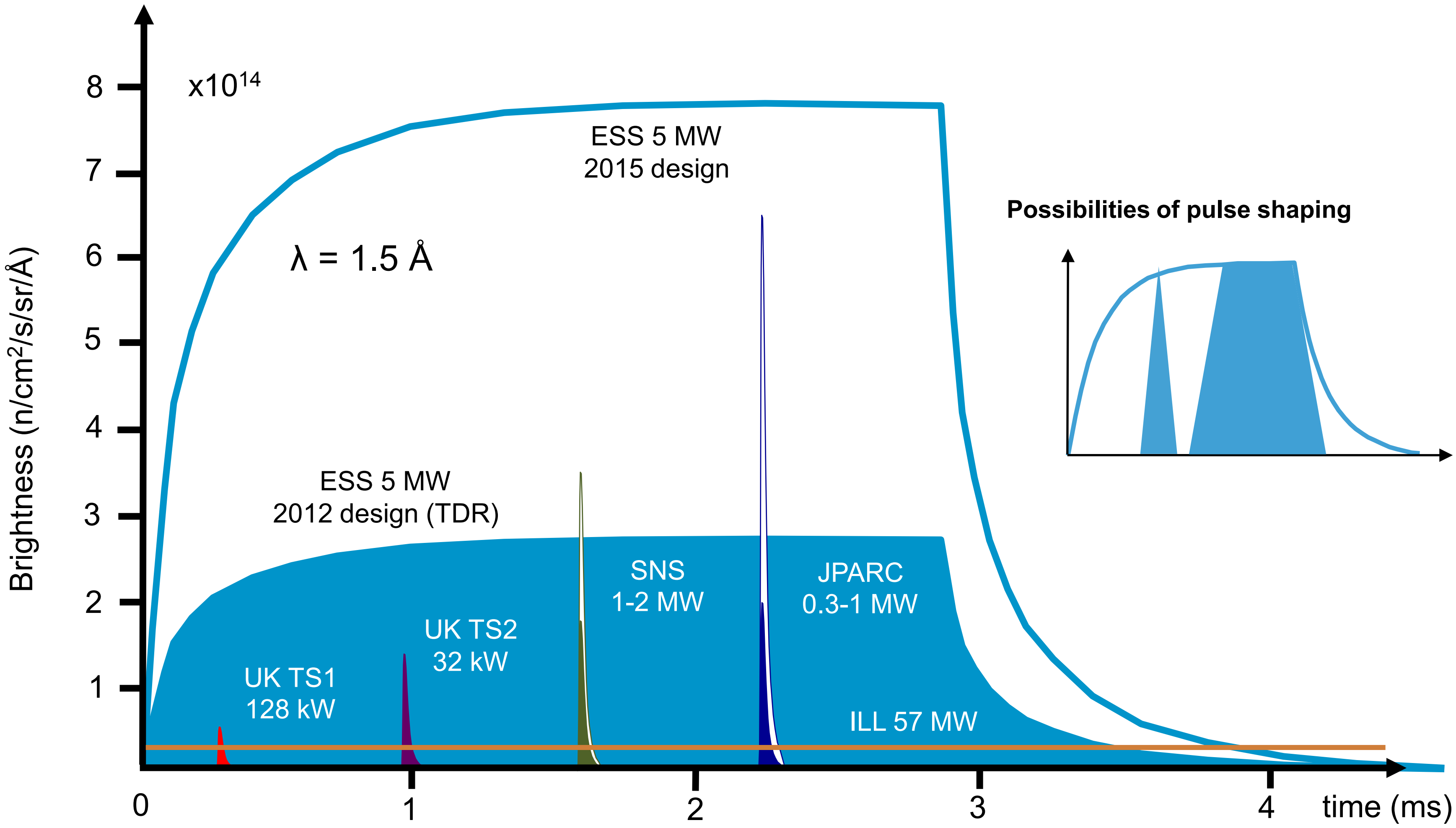
High Power
Linear Accelerator:
• Energy: 2 GeV
• Rep. Rate: 14 Hz
• Current: 62.5 mA
Target Station:
• He-gas cooled rotating W-target (5MW average power)
• 42 beam ports
Ion Source
Total cost: 1843 MEuros 2013

ESS design

EUROPEAN SPALLATION SOURCE



Long-pulse performance



Financing includes cash and deliverables

EUROPEAN SPALLATION SOURCE

Host Countries of Sweden and Denmark

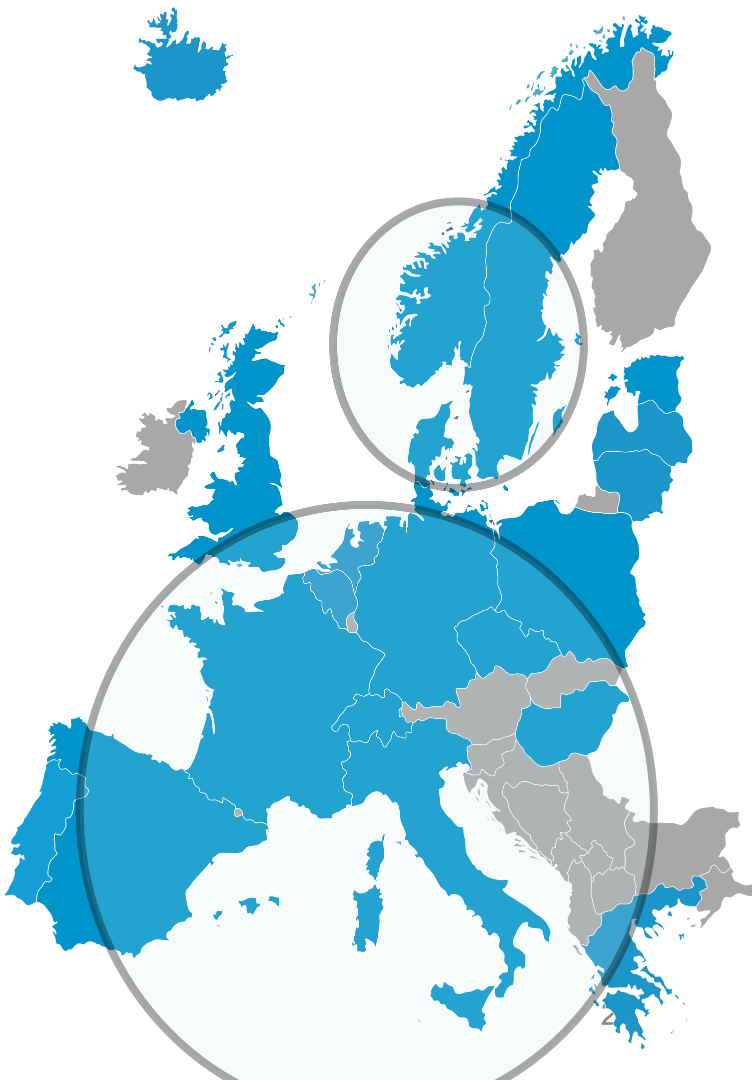
Construction 47.5%
Operations 15%

In-kind Deliverables ~ 3%
Cash Investment ~ 97%

Non Host Member Countries

Construction 52.5%
Operations 85%

In-kind Deliverables ~ 70%
Cash Investment ~ 30%



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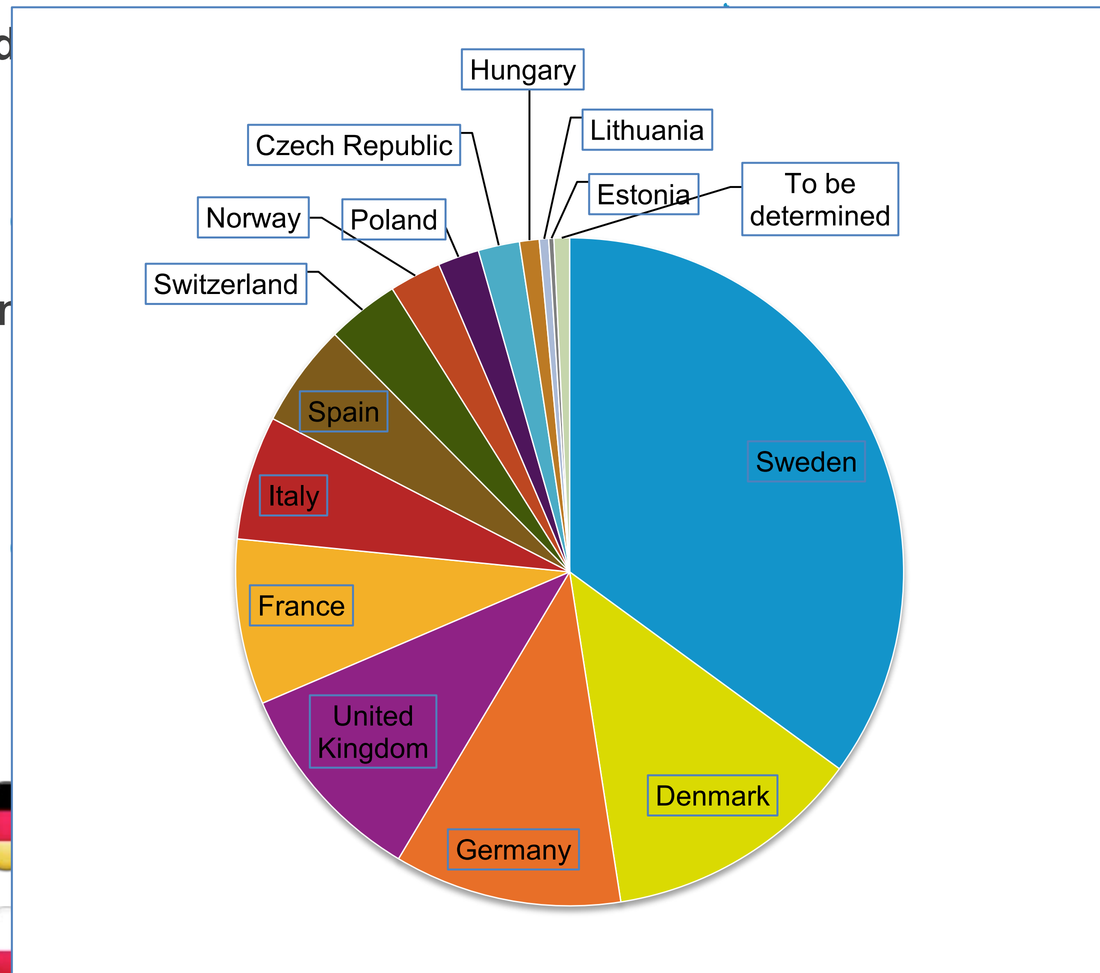
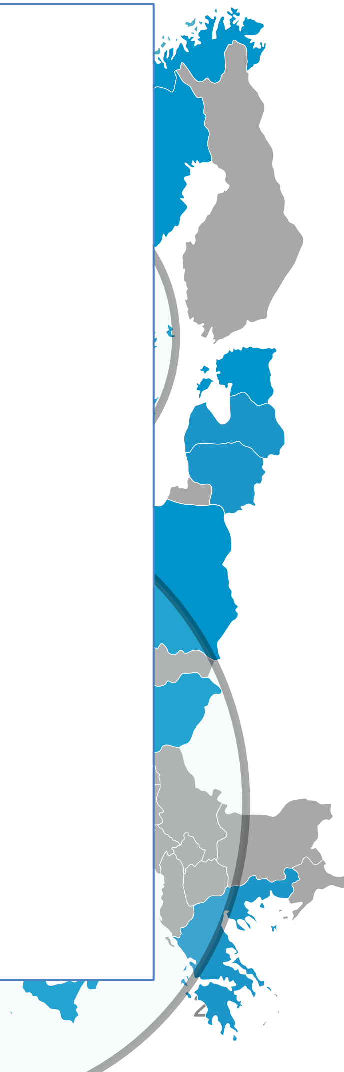
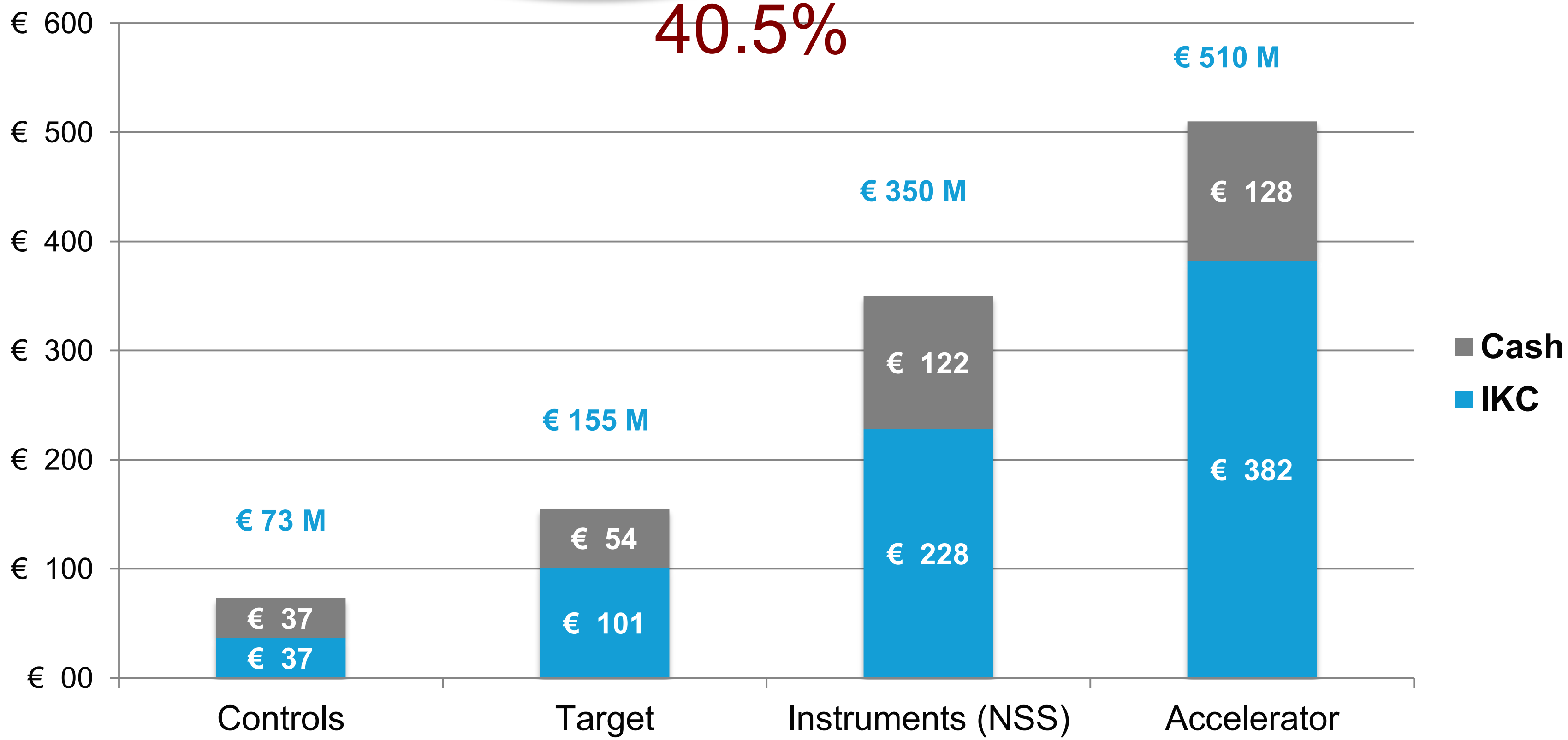




ESS In-kind goals

Construction cost: € 1.84 Billion
In-kind: € 747.5 Million

40.5%



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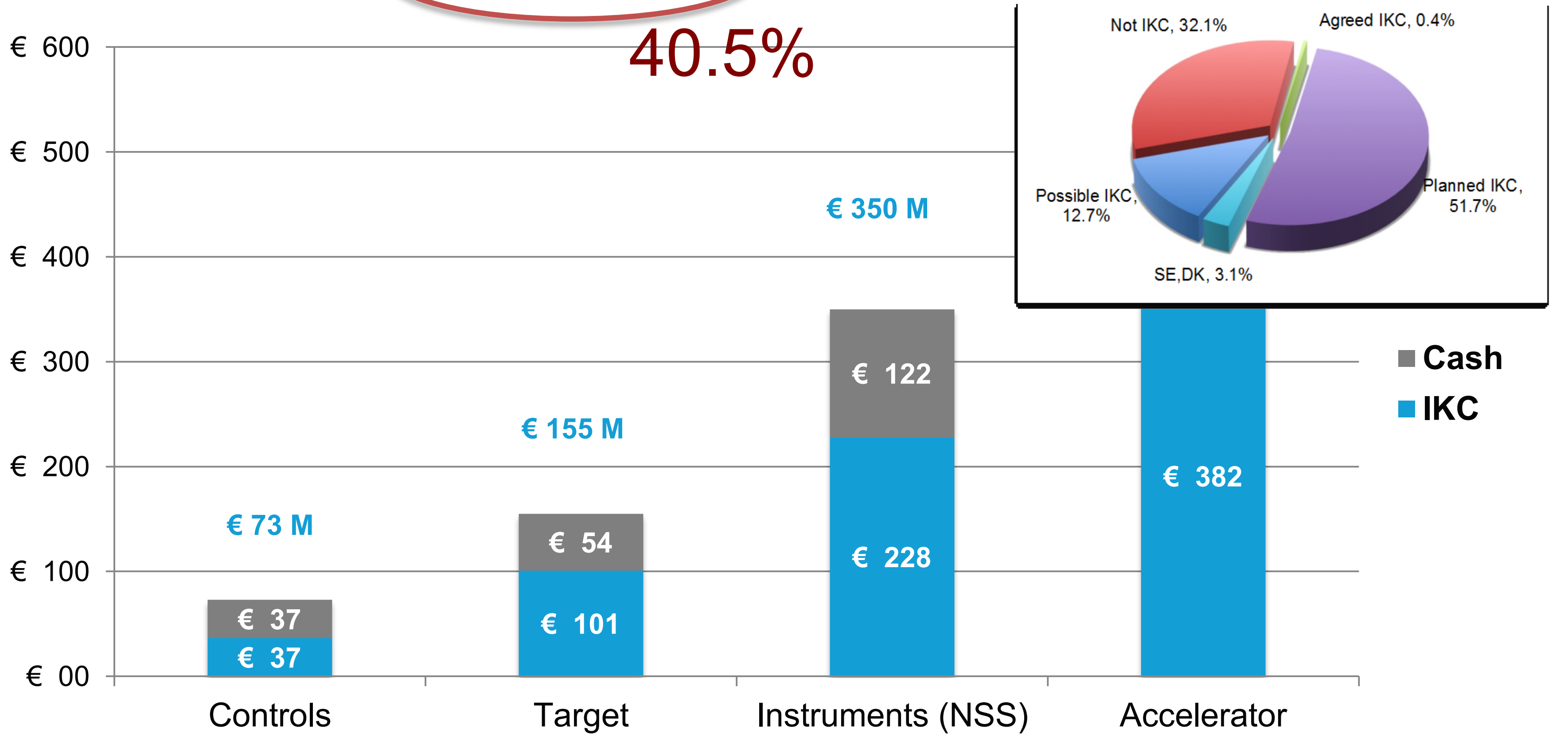
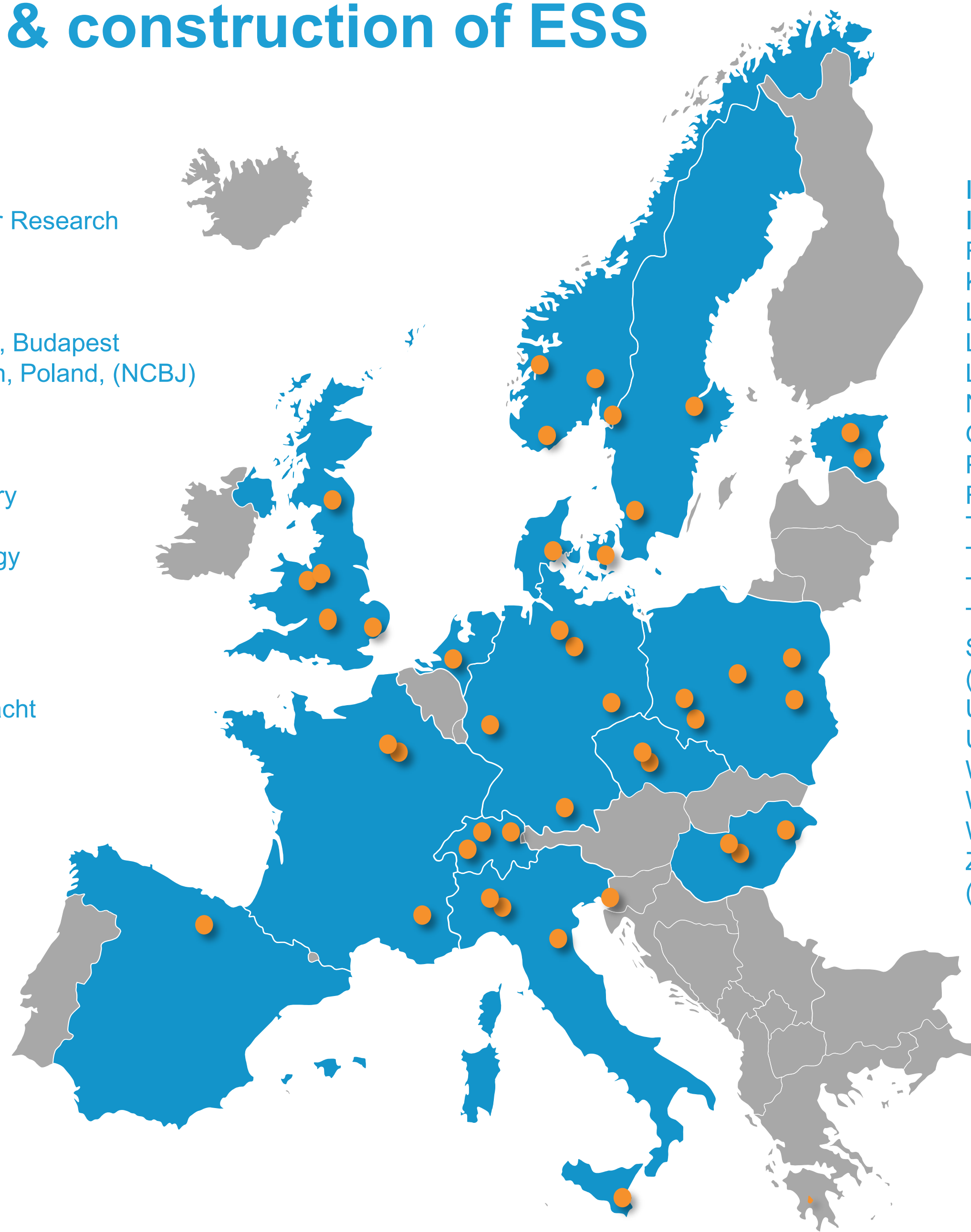


Partner institutions responsible for delivering the design & construction of ESS

Aarhus University
Atomki - Institute for Nuclear Research
Agder University
Bergen University
CEA Saclay, Paris
Centre for Energy Research, Budapest
Centre for Nuclear Research, Poland, (NCBJ)
CERN, Geneva
CNR, Rome
CNRS Orsay, Paris
Cockcroft Institute, Daresbury
DESY, Hamburg
Delft University of Technology
Edinburgh University
Elettra – Sincrotrone Trieste
ESS Bilbao
Forschungszentrum Jülich
Helmholtz-Zentrum Geesthacht
Huddersfield Univesrity
IFJ PAN, Krakow
INFN, Catania
INFN, Legnaro
INFN, Milan



Institute for Energy Research (IFE)
Institut Laue-Langevin (ILL)
Rutherford-Appleton Laboratory, Oxford (ISIS
Kopenhagen University
Laboratoire Léon Brilouin (LLB)
Lodz University of Technology
Lund University
Nuclear Physics Institute of the ASCR
Oslo University
Paul Sherrer Institute
Roskilde University
Tallinn Technical Univesrsity
Technical University of Chemnitz
Technical University of Denmark
Technical University Munich
Science and Technology Facilities Council (STFC)
University of Tartu
Uppsala University
WIGNER Research Centre for Physics
Wroclaw Univesrity of technology
Warsaw University of Technology
Zurich University of Applied Sciences (ZHAW)

Accelerator Division – Scope
Accelerator Technical performances

Design Drivers:

High Average Beam Power

5 MW

High Peak Beam Power

125 MW

High Availability

Key parameters:

-2.86 ms pulses

-2 GeV

-62.5 mA peak

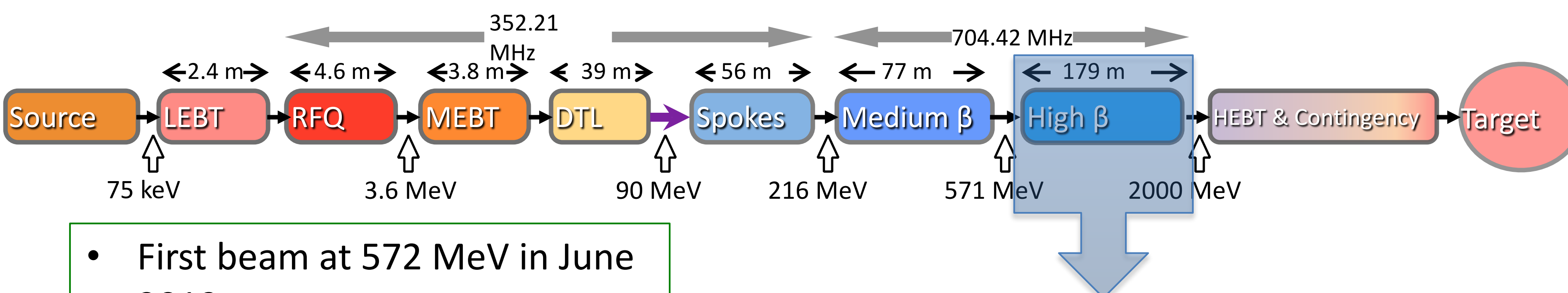
-14 Hz

-Protons (H+)

-Low losses

-Minimize energy use

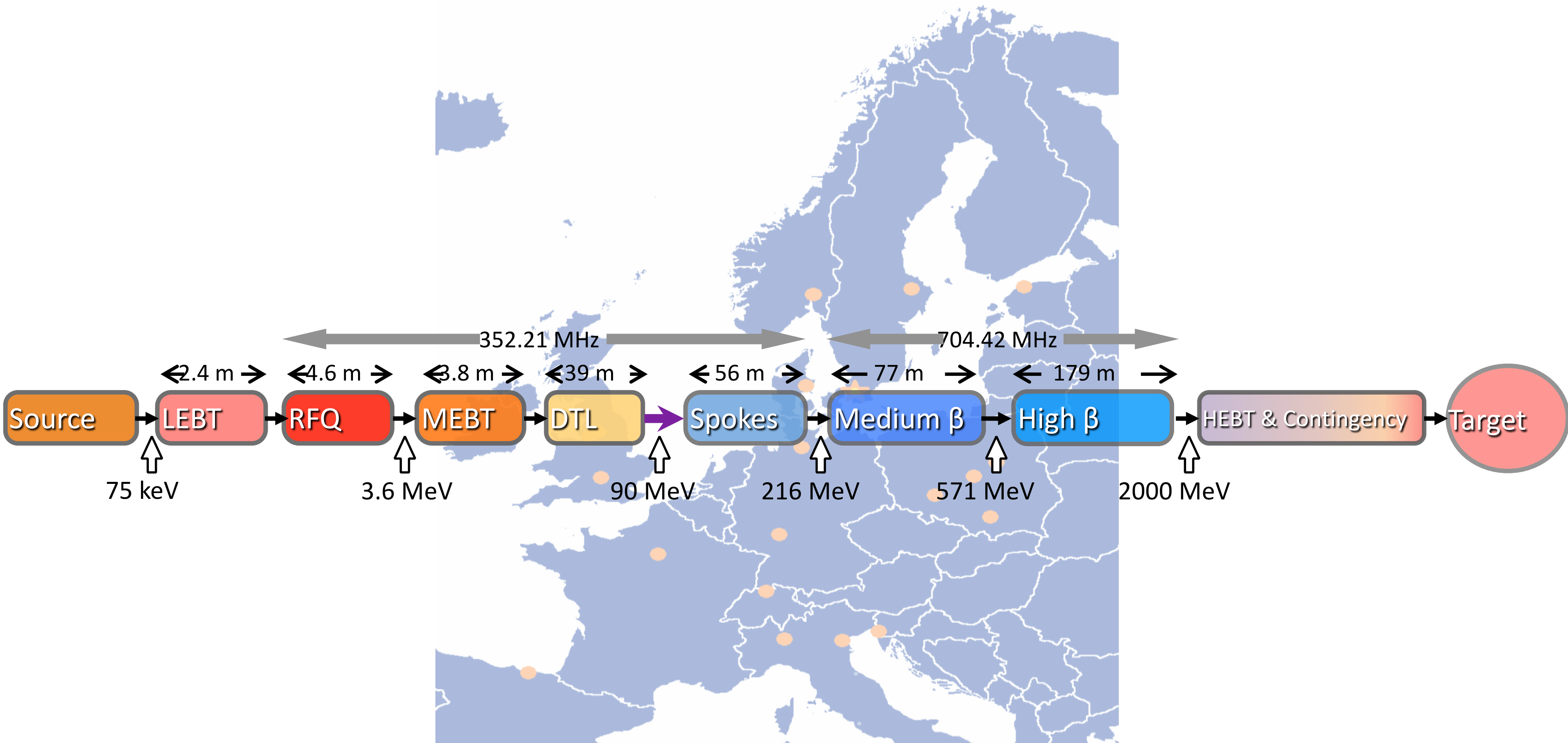
-Flexible design for mitigation and future upgrades

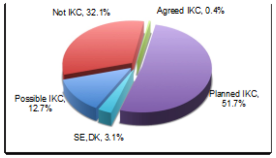


- First beam at 572 MeV in June 2019
- 5 MW capacity for 2023

RF sources for HB part is the scope contingency for accelerator

Accelerator Collaboration - Accelerator





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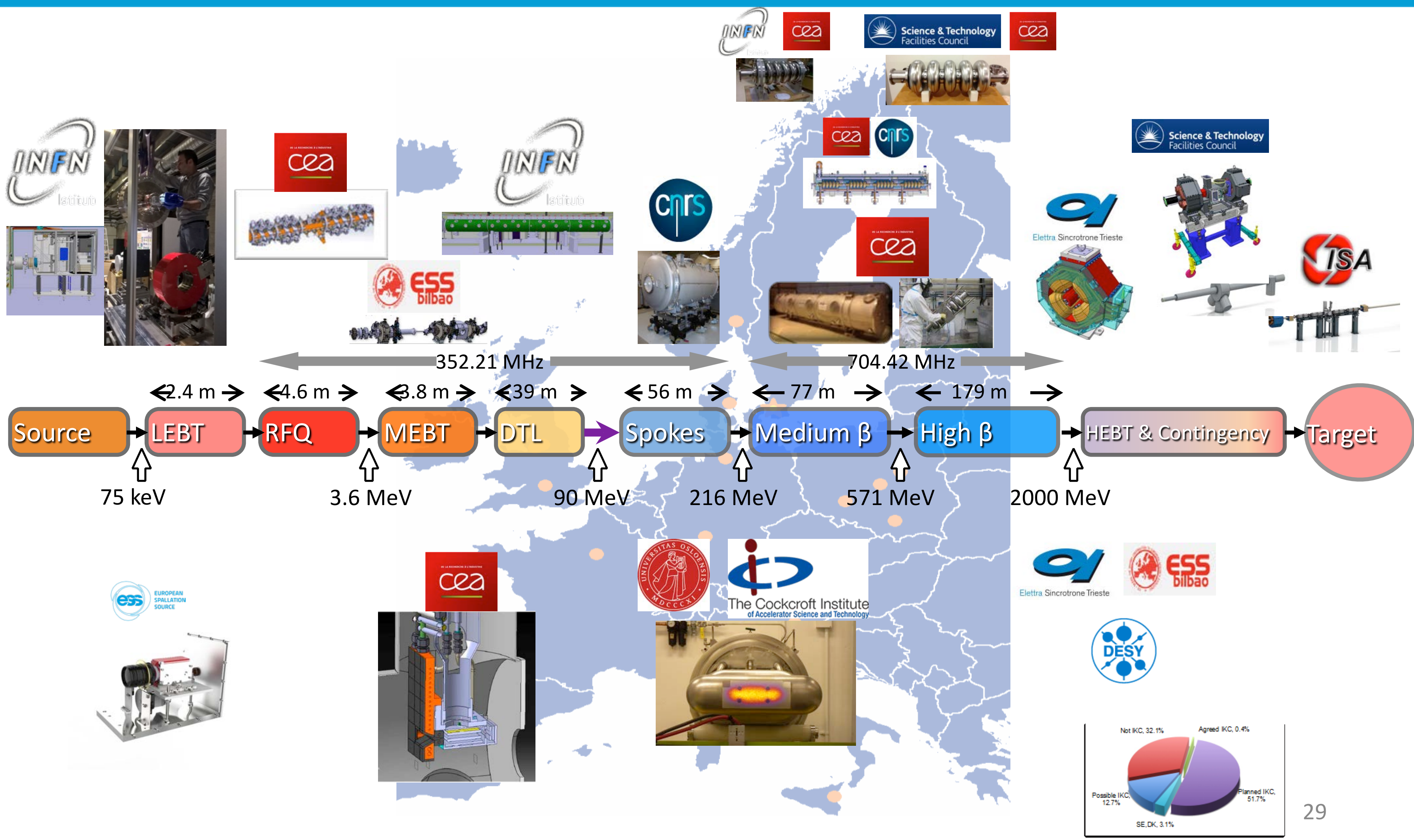
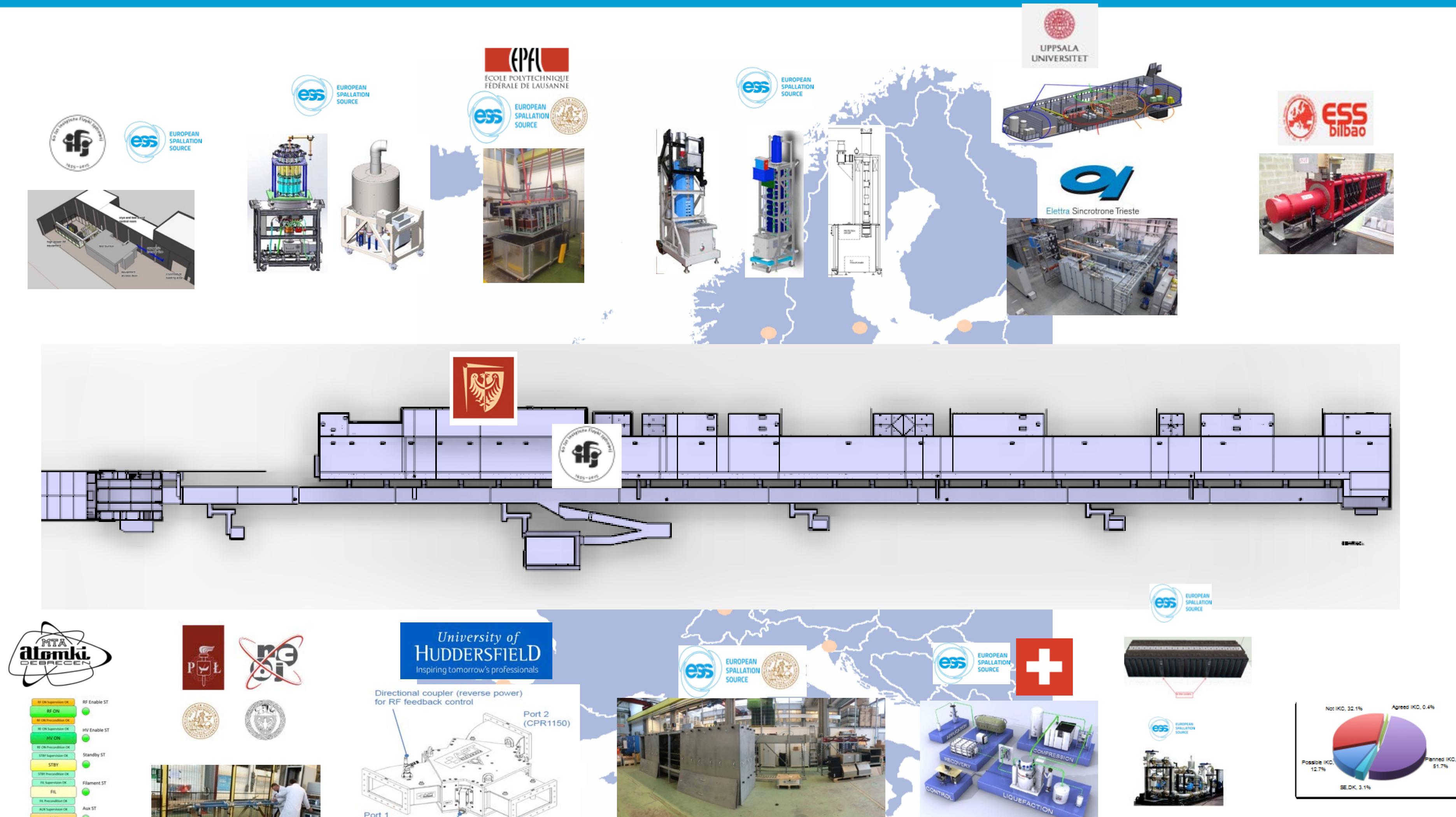


Accelerator Collaboration – RF and STS



Concept, courtesy of GRE (UK)

ACCSYS Major In-kind

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Open in-kind contributions

Topic	Value (k€)	
Cold linac wire scanners	274	
Beam instrumentation for target and tuning beam dump	564	
Medium-beta klystrons	10 965	
High-beta klystrons or IOTs	26 135	
Cables, power distribution cabinets	1 600	
Design, construction, installation of water cooling skids and pipes	2 000	
High-beta modulators	23 507	EPFL?

Although several of these are large commercial items with little or small potential for developments but with large commercial risk, potential interest has been expressed by a few partners.

Total remaining possible IK is 65 045 k€

High Level Master Schedule (Level 1)

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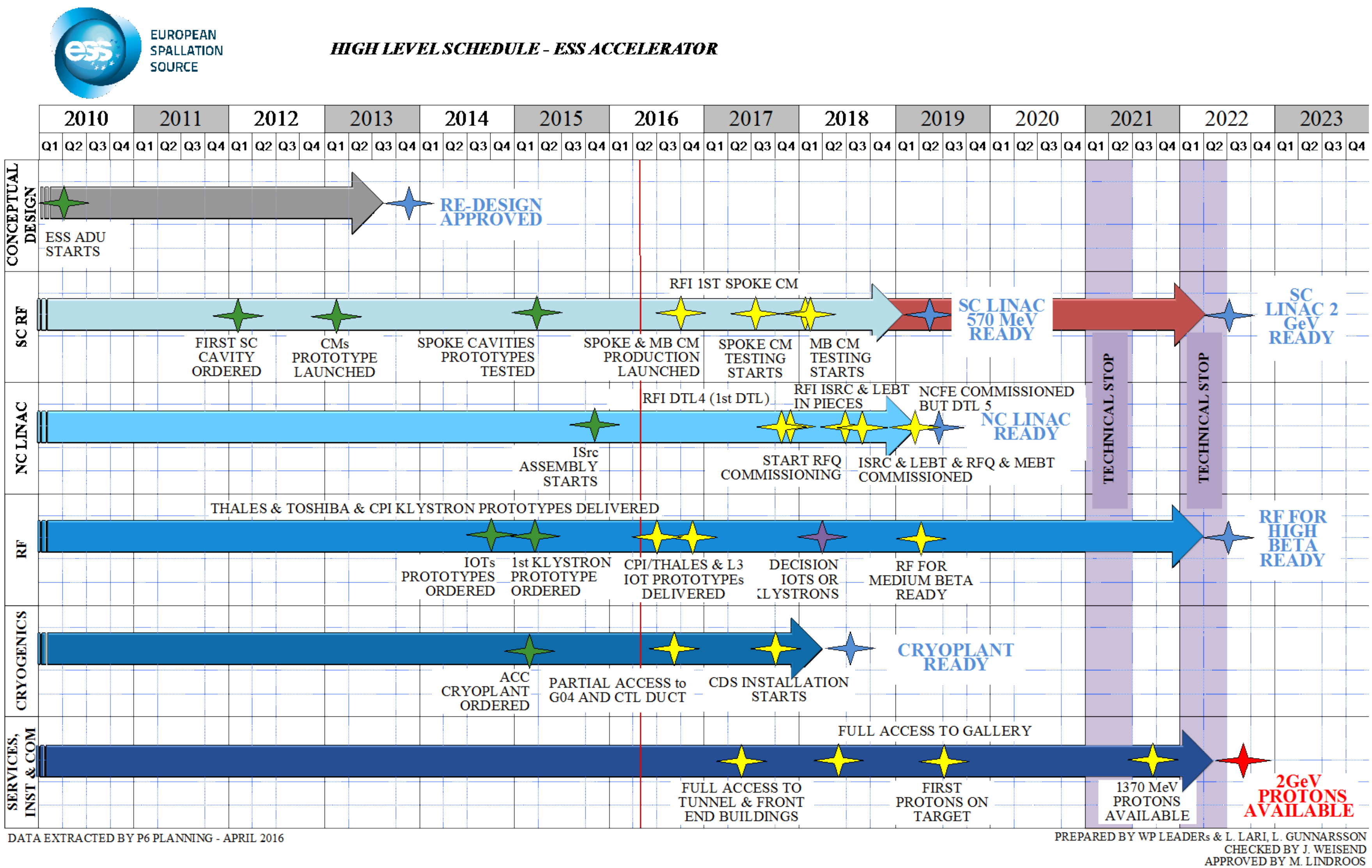
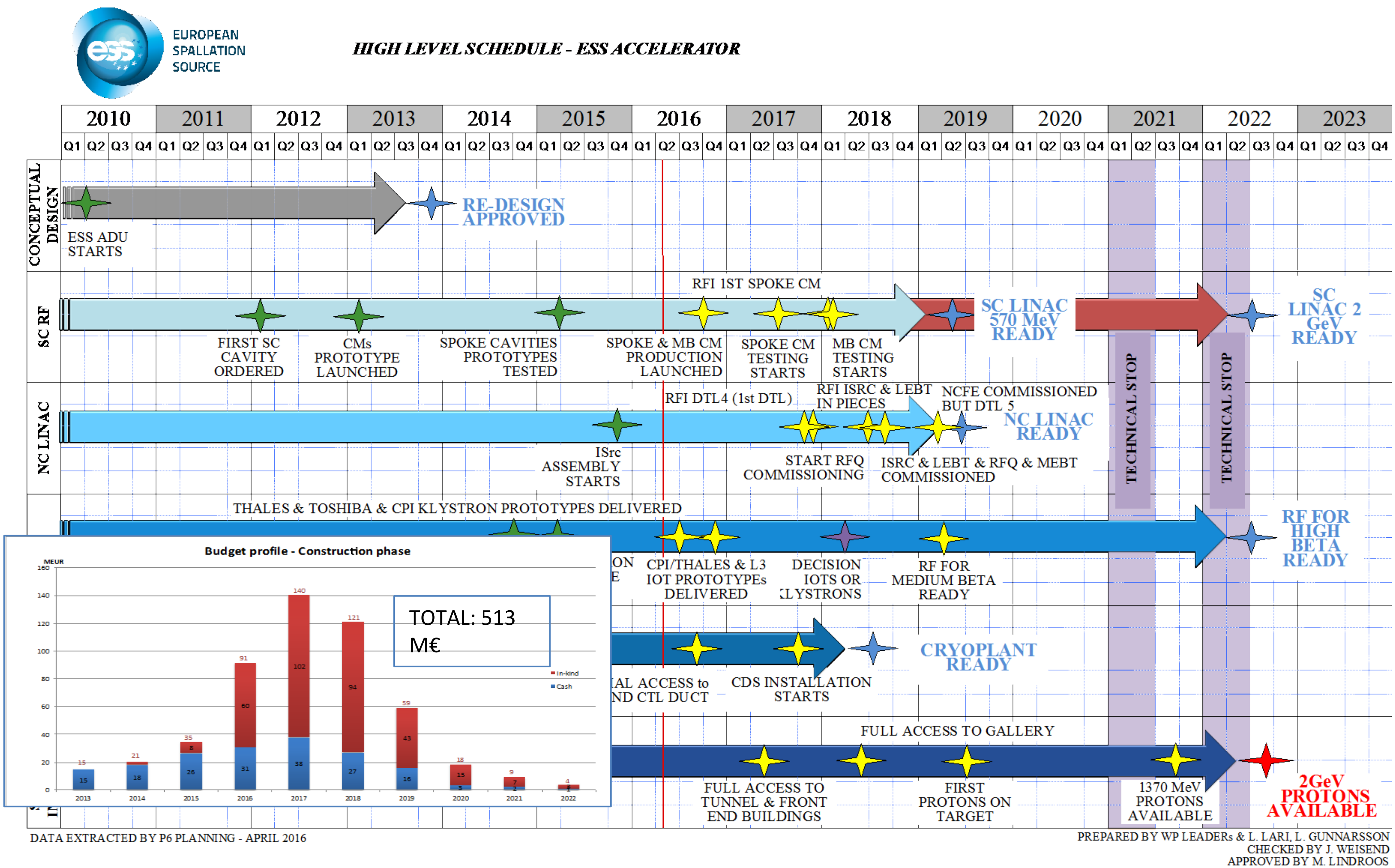


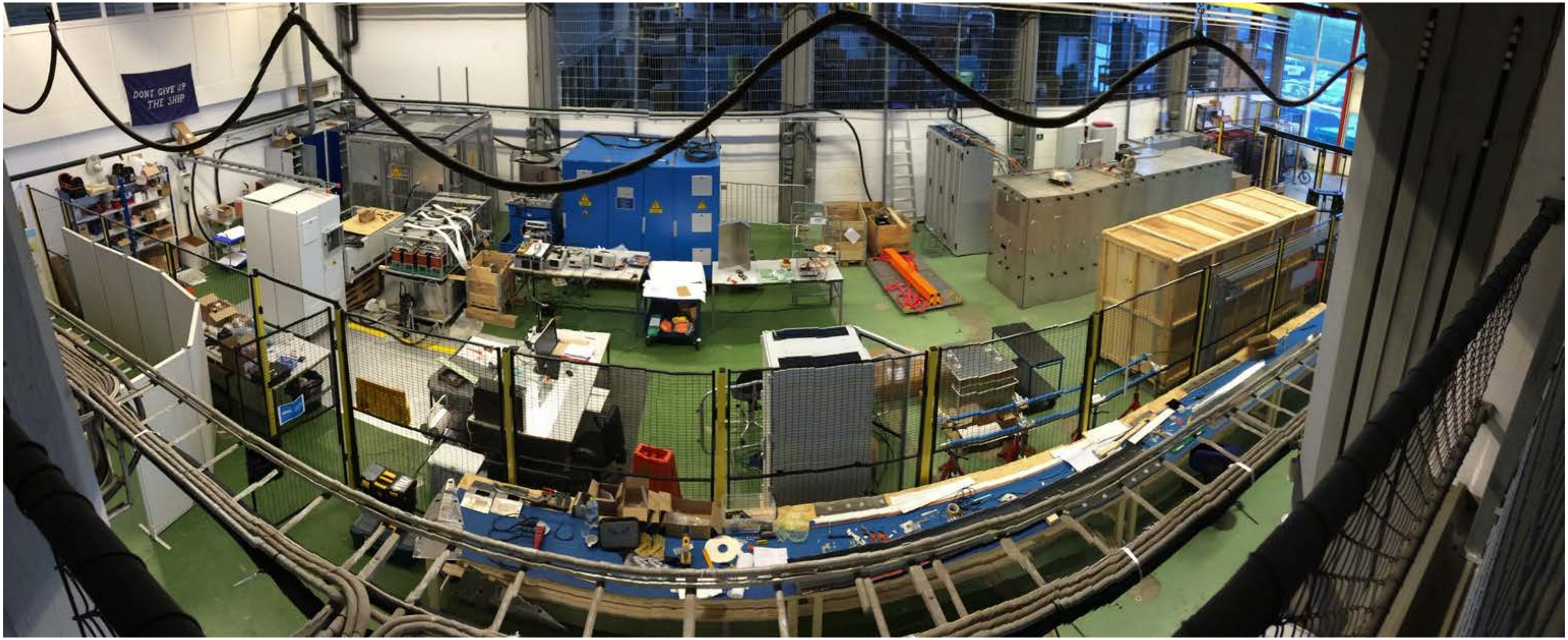
High Level Master Schedule (Level 1)



Integration Test Stand – Getting our hands dirty!



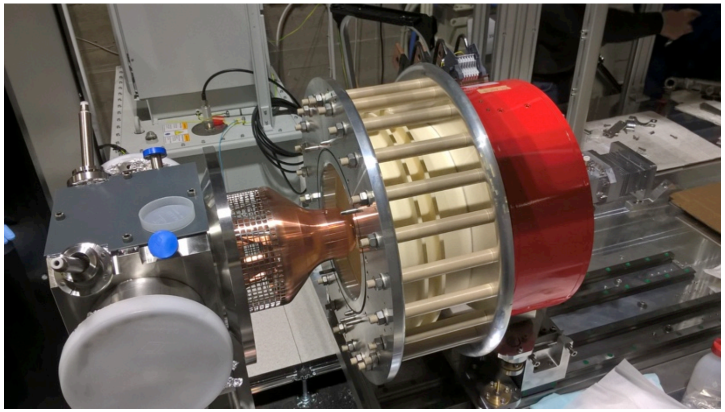


Integration Test Stand – Getting our hands dirty!

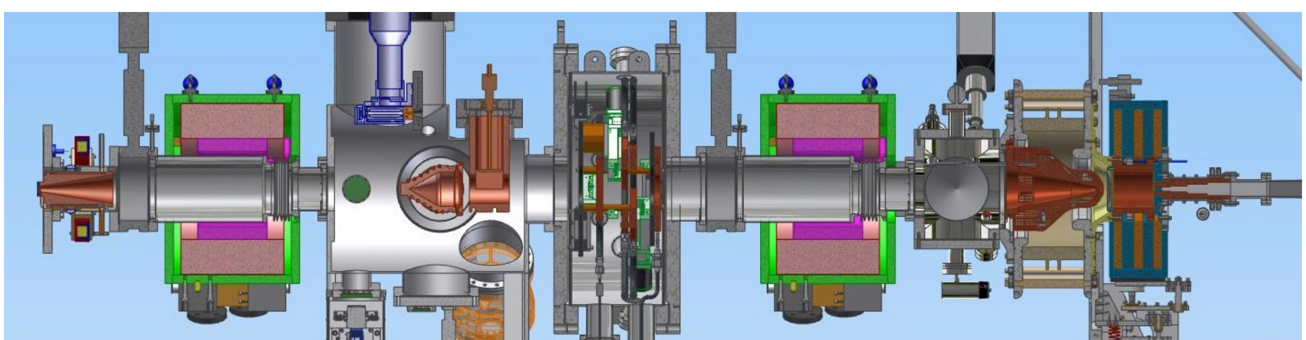
- Early in 2009 after the ESS site decision the accelerator division (AD) consisted of two person, today we are 86
- Forming an ESS accelerator collaboration permitted us to early launch a design update and start IK prototyping based on mature designs from very experienced partners
- The small ESS team initially focused on the Technical requirements, cost book, schedule, finding in-kind partners and recruitment
- After a few internationally renowned experts joined AD, it permitted some Technical development work to start in Lund e.g. Modulator development, cryogenics work, beam instrumentation and more
- Today AD focuses on Project management, some technical developments, integration work, technical coordination, installation and RATS planning, commissioning planning and operation planning.

Microwave Discharge Ion Source (MDIS)



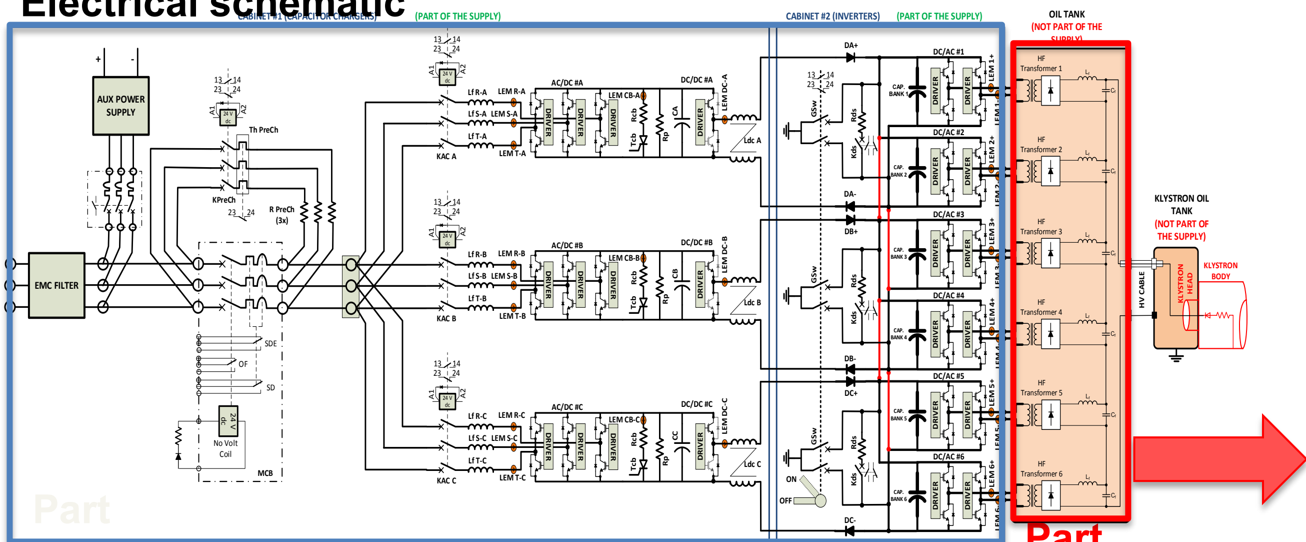
Parameters	Value
Nominal proton peak current	74 mA
Proton fraction	> 80 %
Stable operation current range	60-74 mA
Current stability(over 50us period)	± 2 %
Pulse to pulse variation	± 3.5 %
Beam Energy	75 keV (±0.01)
Distance between pulses	1 Hz< f <14 Hz
Restart after vacuum break Restart after cold start	<32 h <16 h

Parameters	Value
Beam current change (2 mA step, ±1 mA res.)	2-74 mA
Nominal pulse length	2.86 ms
Pulse length range (±0.001 ms)	0.005-2.88 ms
99 % rms norm. emit. at RFQ input	< 2.25 pi.mm.mrad
Twiss parameter: α	α= 1.02 ±20%
Twiss parameter: β	β= 0.11 ±10%
Rise and fall time	<20 us
Maximum LEBT pressure	6e-5 mbar



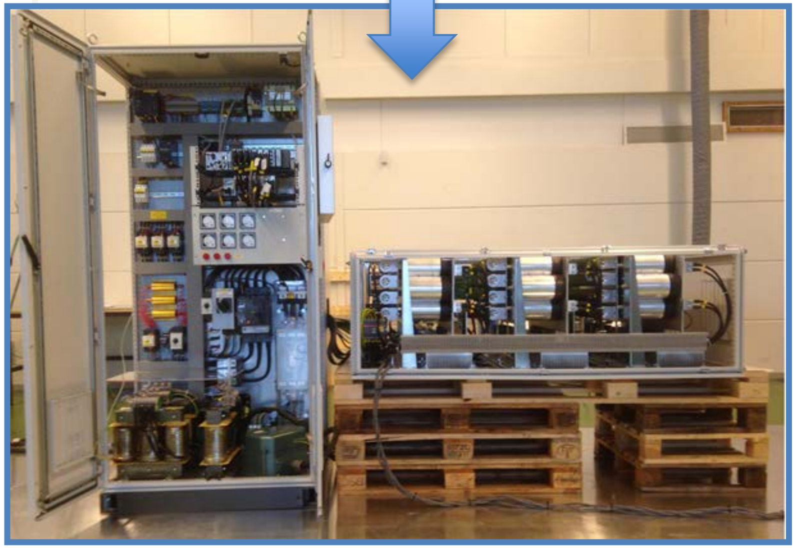
Modulator SML proto status March 2016

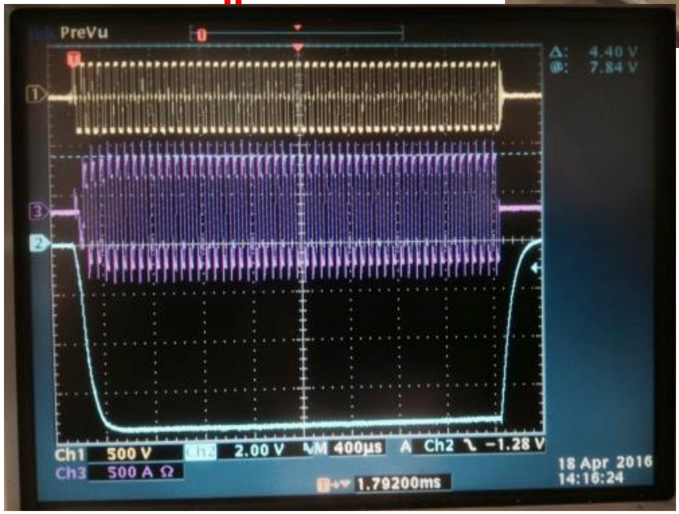
Electrical schematic



Part I

Part II





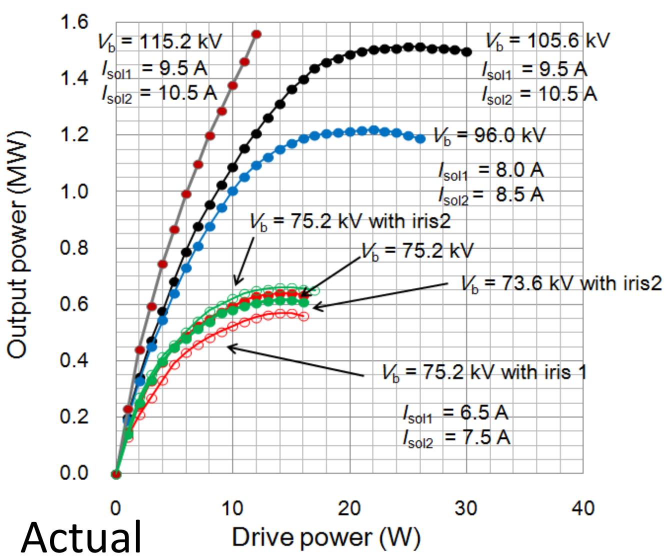
90 kV operation

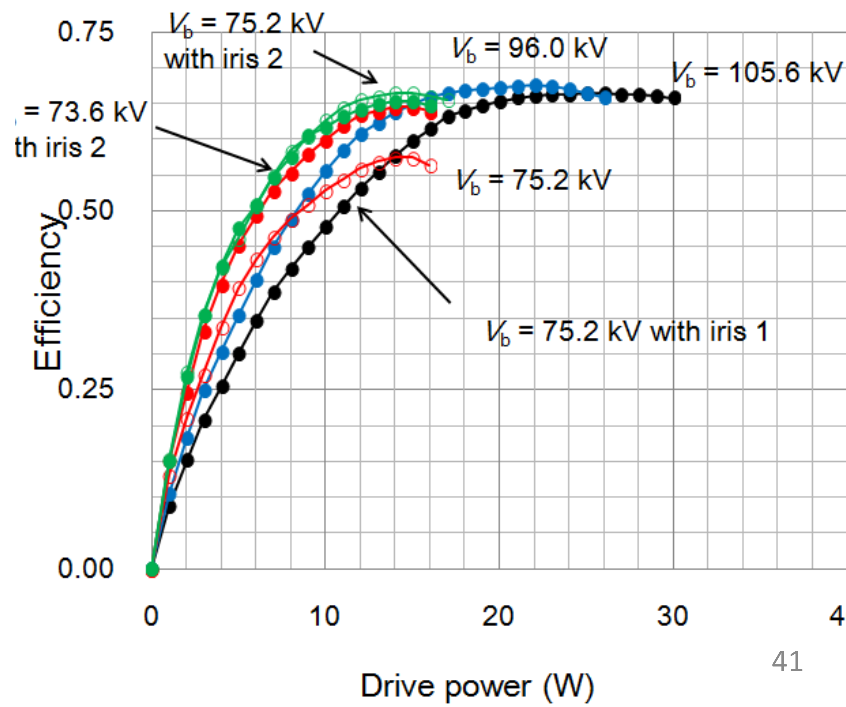
Closed loop

Medium beta klystrons

- The Toshiba prototype passed FAT in February and has been delivered to ESS
- Thales and CPI klystrons due May and July respectively
- Operation at low voltage and use of iris on the output maintains high efficiency even at reduced power levels

Actual Toshiba klystron



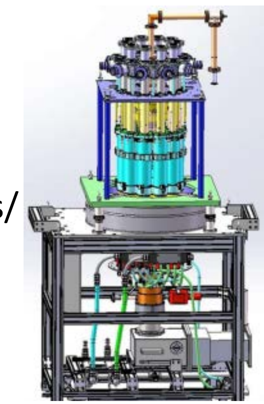


Multi beam IOT

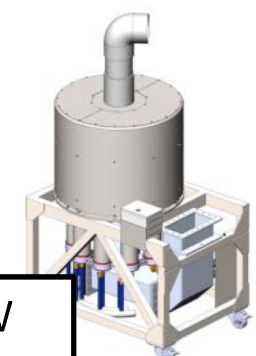
- L3 IOT FAT started last week (contractual date October 2016)
- 15 kW solid state driver delivered (to L3) for use with factory testing
- Driver, HV PSU, interlocks being testing on the single beam IOT, prior to MB-IOT tests
- L3 extended testing being discussed to follow up on the contractual factory testing

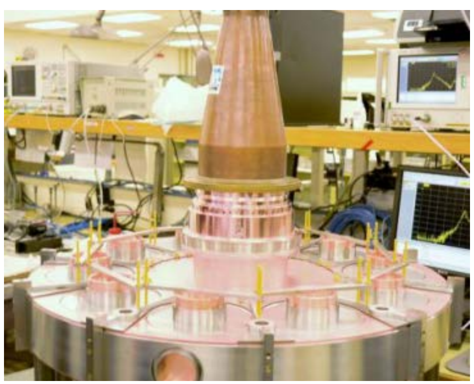
- Thales/CPI IOT is planned for delivery to CERN in July 2016
- Tube will be integrated at CERN by Thales
- CERN test stand (for Thales/CPI) under construction
- Formal Factory testing expected November 2016

Thales/ CPI



L3





L3: Output cavity cold test

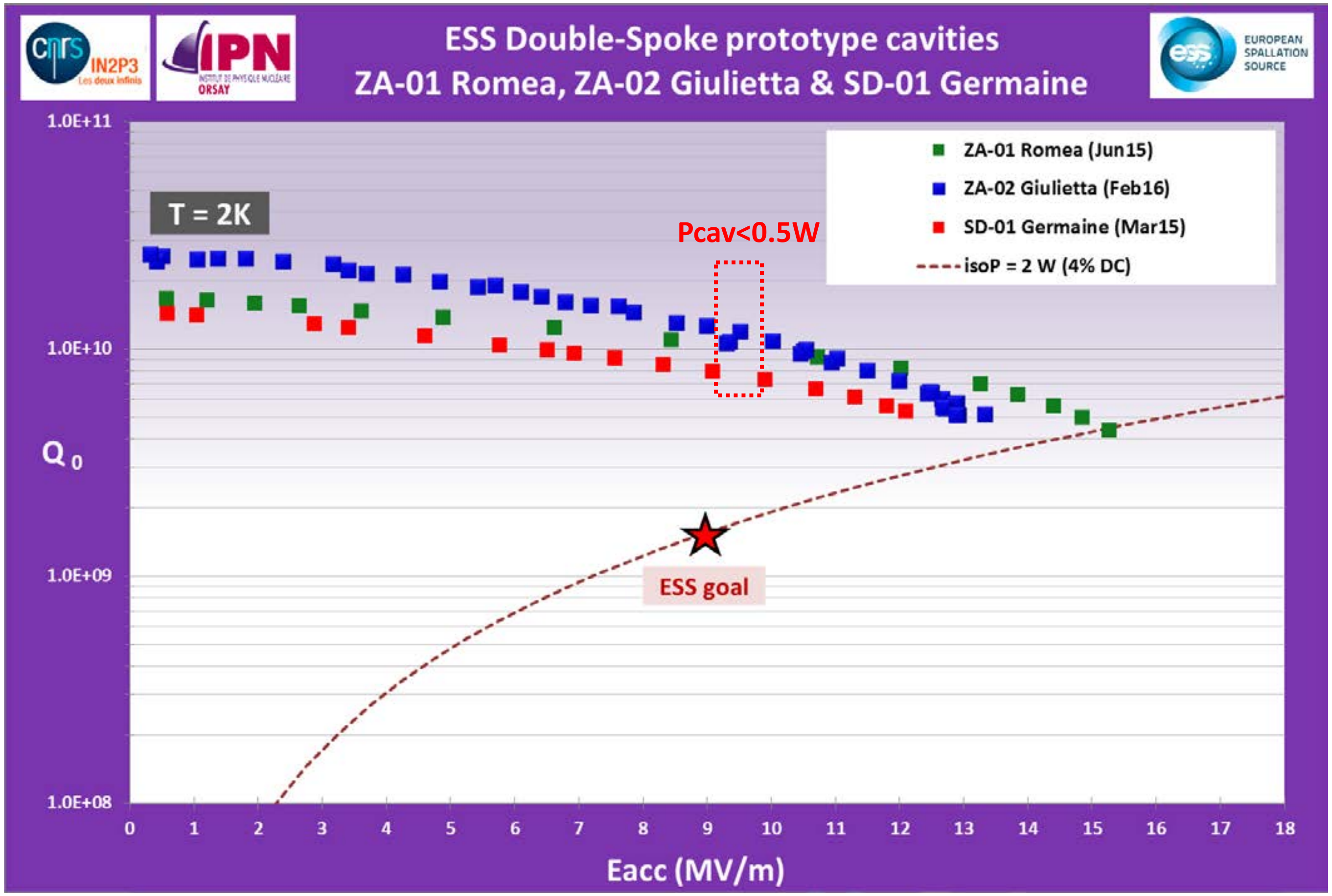
L3: Tube after bake out

L3: 15 kW driver from Tomco

Spoke Cavities design & prototype performances

Spoke cavity prototype test results (Jan15 – Feb16):

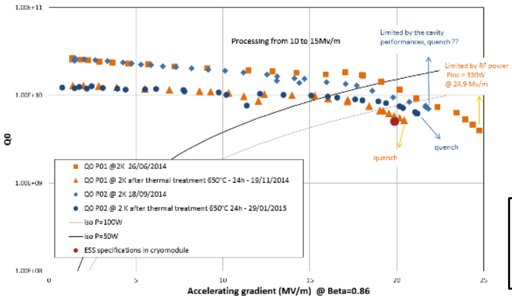
- Excellent performances, well within specifications (both on Eacc & Qo)



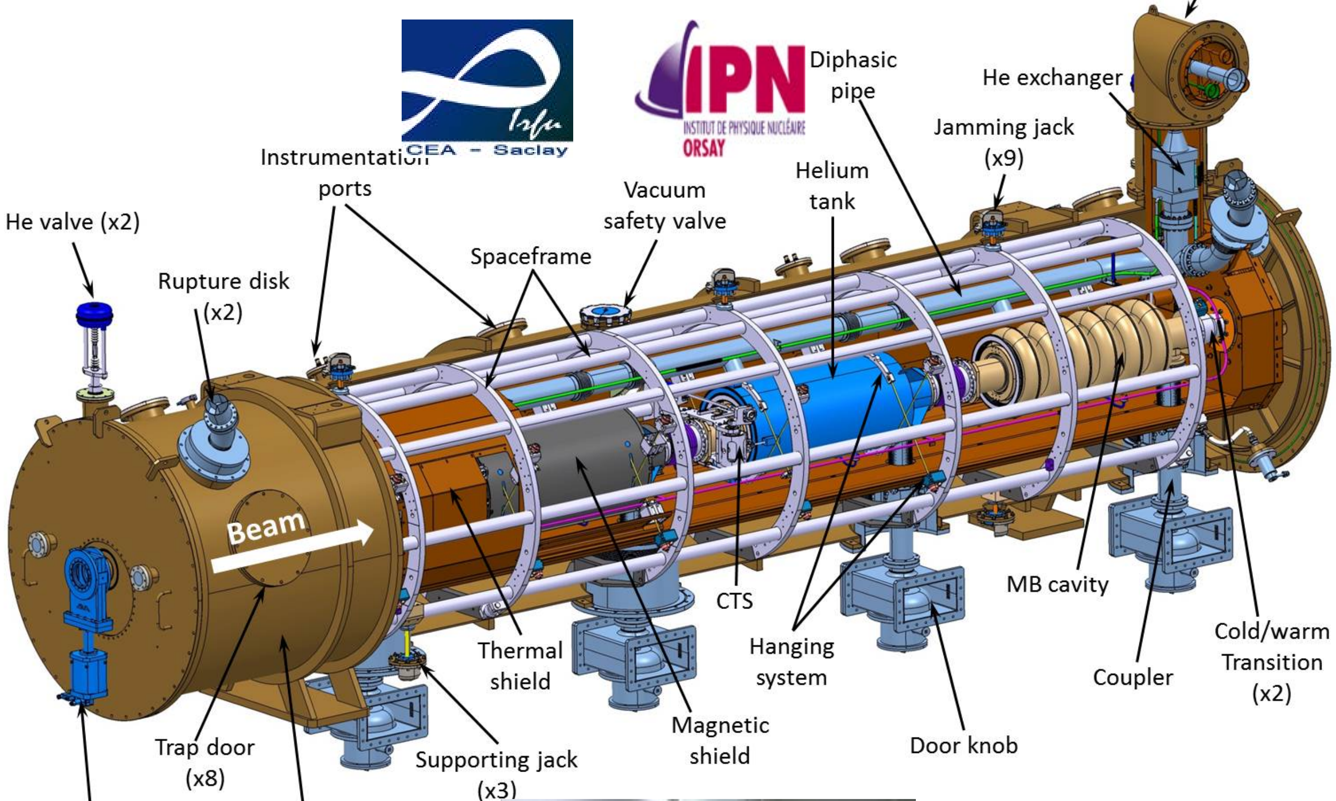
Selected technologies

Medium beta cavity prototype

High beta cavity prototype with its helium tank



Q curve of the High beta prototype cavities



Blank assembly of the spaceframe inside the vacuum tank

Summary

- ESS is well into construction and the accelerator project is progressing according to plan towards first beam at 572 MeV in June 2019
- The ESS facility is built by a collaboration of some 100 research institutes and universities
  - The Accelerator is built with a very high percentage of IK contributions (>50%) with most major accelerator systems being designed, prototypes and built outside ESS and we are still looking for partners!
- Prototypes for the all major accelerator elements are now being assembled and tested and the low energy part is under manufacturing
- The Accelerator Division is recruiting according to plan and will be ready to take ownership of the accelerator, install it, commission it and enter it into operation for the 2019 milestone
- Most future large scale project are likely to be IK projects and this is a very powerful model. Together we are strongest!

Many thanks to all my colleagues in the ESS accelerator collaboration

Thank you for listening!

EUROPEAN SPALLATION SOURCE

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EUROPEAN
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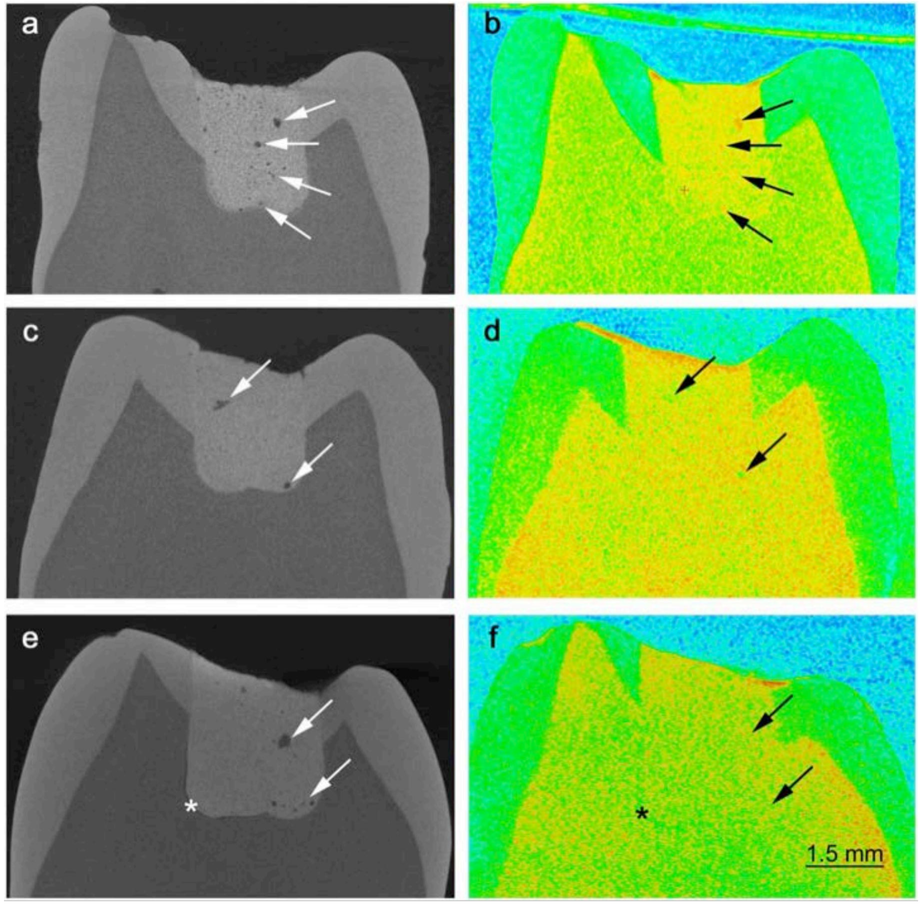
SOURCE


A partnership of
17 European nations
EUROPEAN
SPALLATION
SOURCE

Extracted teeth restored with glass ionomer cement (GIC)



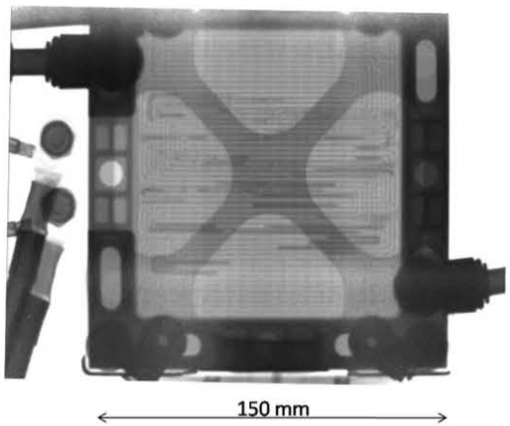
TEAM

Supervisors and contacts: H.N. Bordallo (NBI-KU & ESS), A.R. Benetti (Department of Odontology, KU) M. Strobl (ESS)

Collaborators: Nikolay Kardjilov (HZB), Denis Okhimenko (KU, Chemistry)

Researcher: Marcella C. Berg (PhD Student), Casper Madsen (MSc Student)

Neutron Imaging - Examples

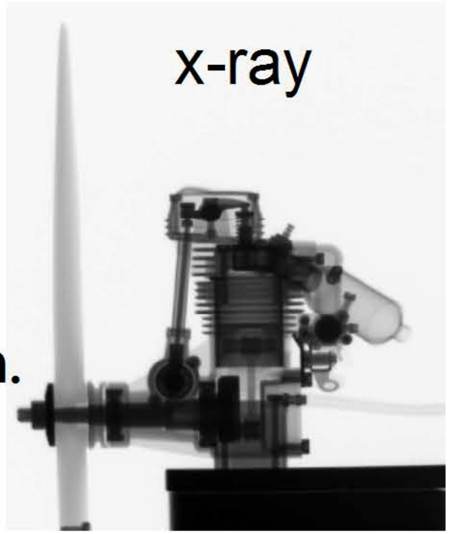


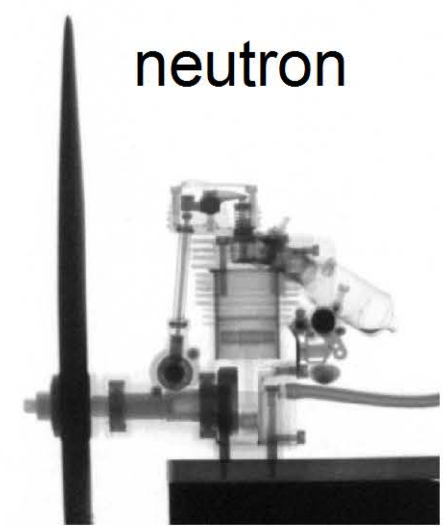
$$I = I_0 \; e^{-\mu . d}$$

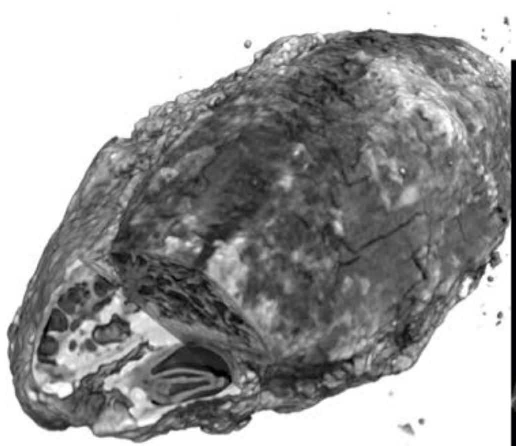
neutron μ different to x-ray

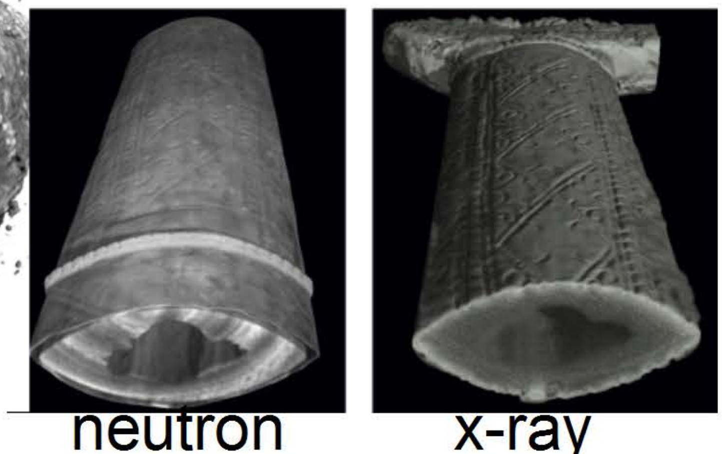
contrast hydrogen / deuterium.

not increasing with Z^2









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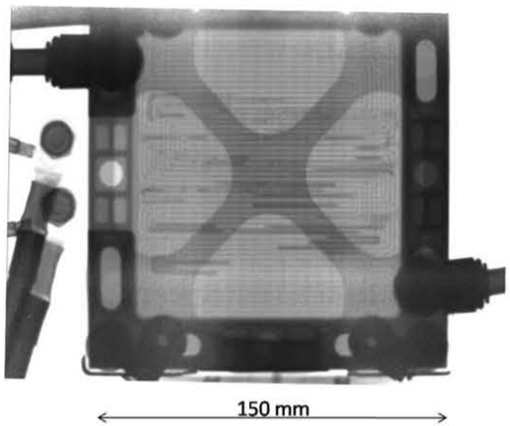
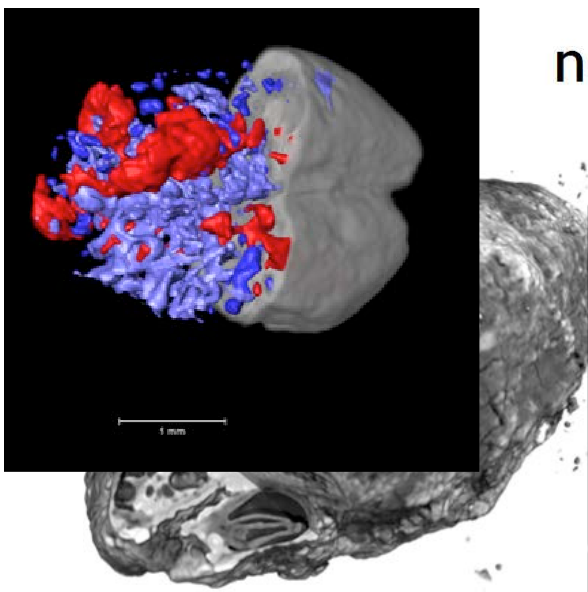
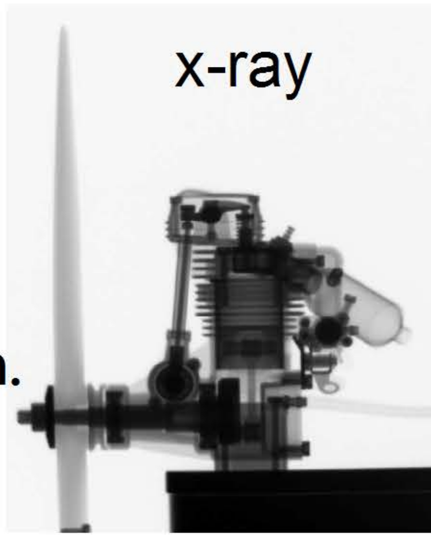
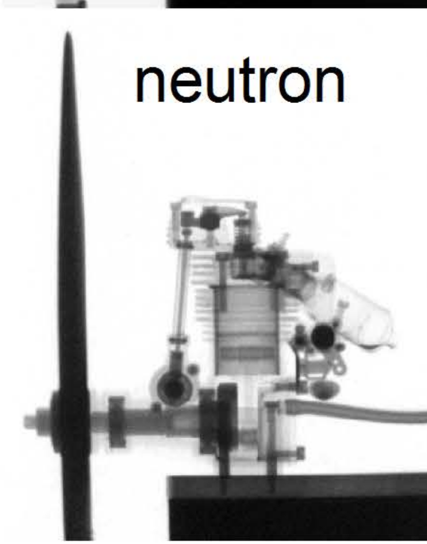




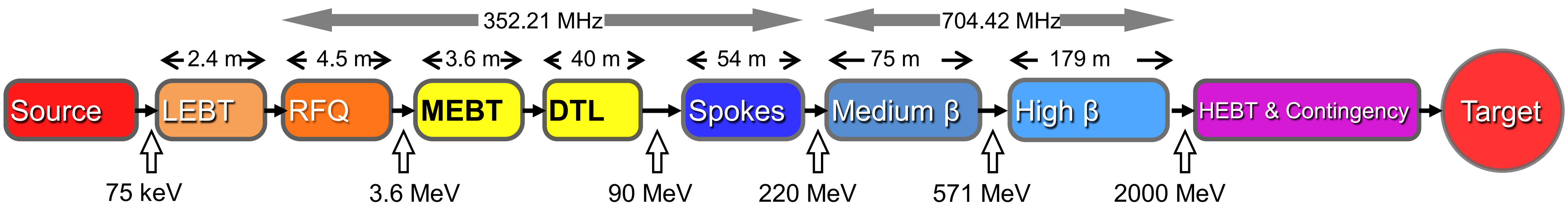
neutron

x-ray





RF Technical performances



	Energy (MeV)	Frequency /MHz	No. of Cavities	βg	Temp / K	RF power /kW
Source	0.075	-	0	–	~300	–
LEBT	0.075	-	0	–	~300	–
RFQ	3.6	352.21	1	–	~300	1600
MEBT	3.6	352.21	3	–	~300	20
DTL	90	352.21	5	–	~300	2200
Spoke	220	352.21	26 (2/CM)	0.5 β_{opt}	~2	330
Medium β	571	704.42	36 (4/CM)	0.67	~2	870
High β	2000	704.42	84 (4/CM)	0.86	~2	1100
HEBT	2000	–	0	–	~300	–

High level accomplishments last year

EUROPEAN SPALLATION SOURCE

- A plan for all **Preliminary and Critical Design Reviews** have been established and is executed and a detailed **plan for installation** has been completed
- **Prototypes** for e.g. Elliptical SC cavities, spoke cavities, modulator, spoke RF amplifiers, klystrons have been completed and are being tested
- The ion source (IS2), the accelerator cryoplant and test stand and instruments cryoplant is under construction. The RFQ and MEBT **manufacturing have been launched** and the DTL manufacturing will be launched in April
- A task force with contracted staff from industry has been set-up to **complete all Technical annexes** for IK contracts
- A **test stand** proposed by last years annual review for integrations tests have been set-up with equipment on loan from CERN and a license to operate the klystron will soon be available
- The **ESS modulator prototype** presently being tested at the test stand, the first ESS 704 MHz klystron has gone through Factory acceptance test and has been received in Lund for testing
- The division has been **re-organized** to avoid split responsibility for WPs between groups and to strengthen work on interfaces. The first 3 technicians have been recruited.
- Topical regular **collaboration workshops** have been launched for SCRF and beam instrumentation to strengthen communication and know-ho transfer between all involved partners