

ESS PROGRESSING INTO CONSTRUCTION

Mats Lindroos

Head of accelerator at ESS

Adjungated Professor at Lund University, Physics

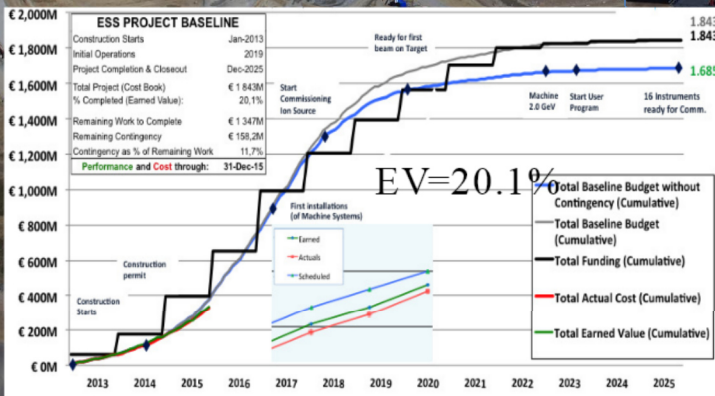
And the ESS accelerator collaboration

www.europeanspallationsource.se

23 May 2016

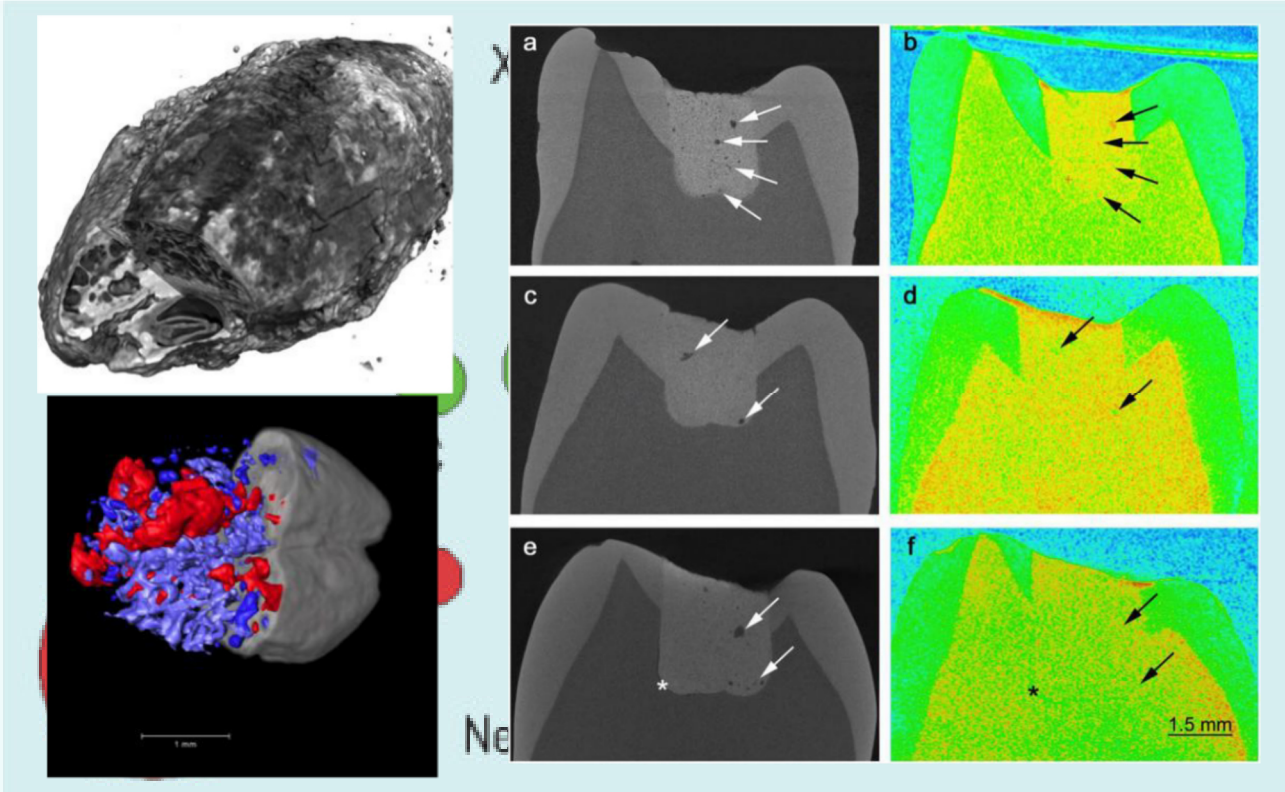


Progress on civil construction



27 April 2016

Neutrons and light: similar but still different



Its discovery
James Chadwick
1932
(α, n) reaction

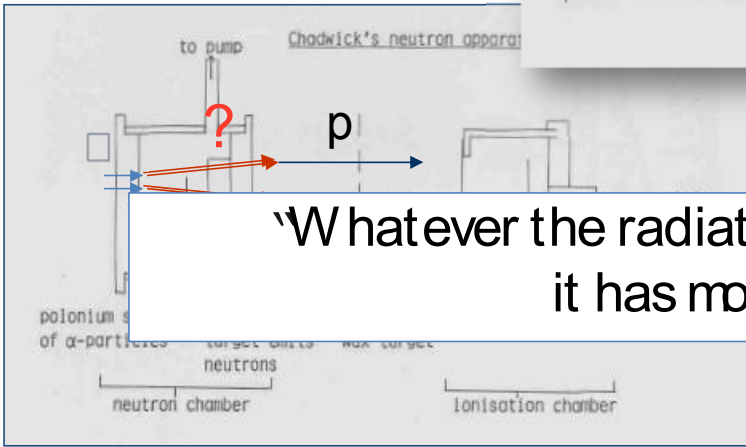
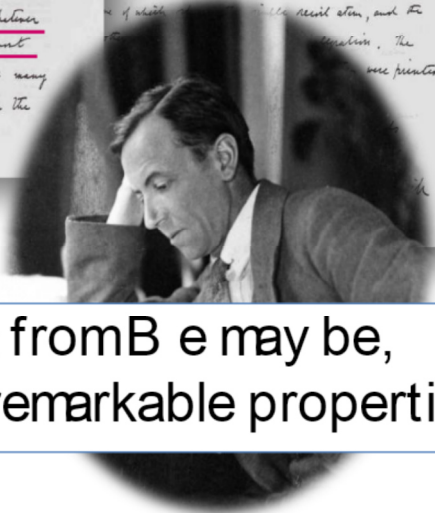
Cambridge University,
Cambridge.
26 February 1932.

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 net 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

letter to 'Nature' and they can all be interpreted readily on the assumption that the particles are neutrons. Feather has taken some pictures in the dispersion chamber and we have already found about 20 cases of recoil atoms. About 4 of these show an abrupt ^{or fork} and it is almost certain that ~~the~~ one seen in this fork represents a recoil atom and the other some other particle, probably an α particle. They are disintegrated due to the capture of the neutron by O or Os . I enclose two photographs of what I think is a recoil atom, and the α particle from the same reaction. The α particle was printed



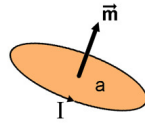
“Whatever the radiation from Be may be, it has most remarkable properties”

Neutrons are beautiful!

Wave



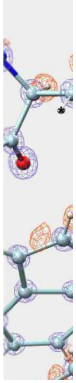
Magnetic moment



Particle



Neutral

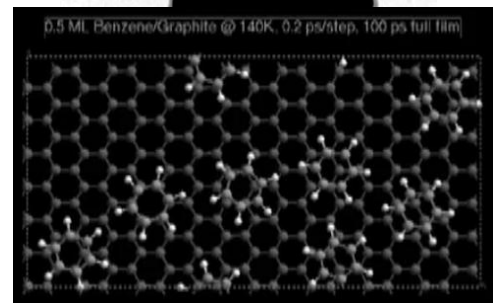
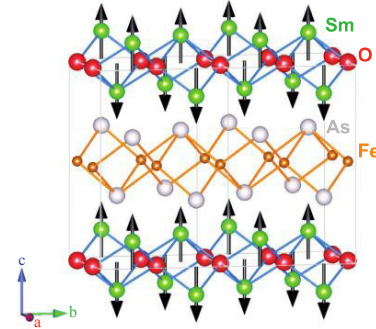


Diffractometers - Measure structures

— Where atoms and molecules are

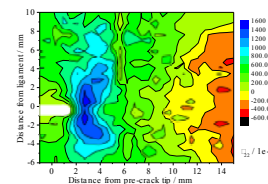
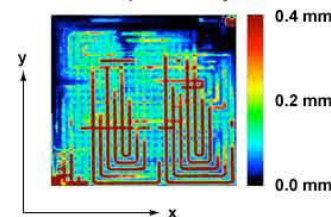
Spectrometers - Measure dynamics

— What atoms and molecules do

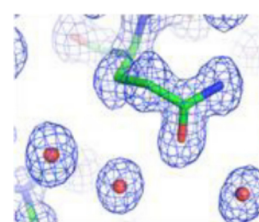


- Higher (Room?) Temperature Super Conductors
- Hydrogen storage substrate
- Efficient membrane for fuel cells
- Flexible and highly efficient solar cells
- Understanding liquid membranes
- Nano scaled structures for controlled drug release
- Self healing materials – smart materials
- Spintronics - Spin-state as a storage of data (10^{23} gain in capacity)
- CO₂ sequestration
- Neutron electric dipole moment
- Neutron oscillations
- And much more...

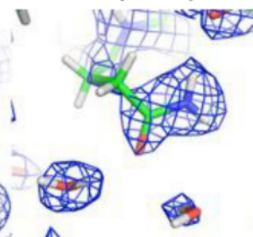
Image of water distribution with thickness represented by color



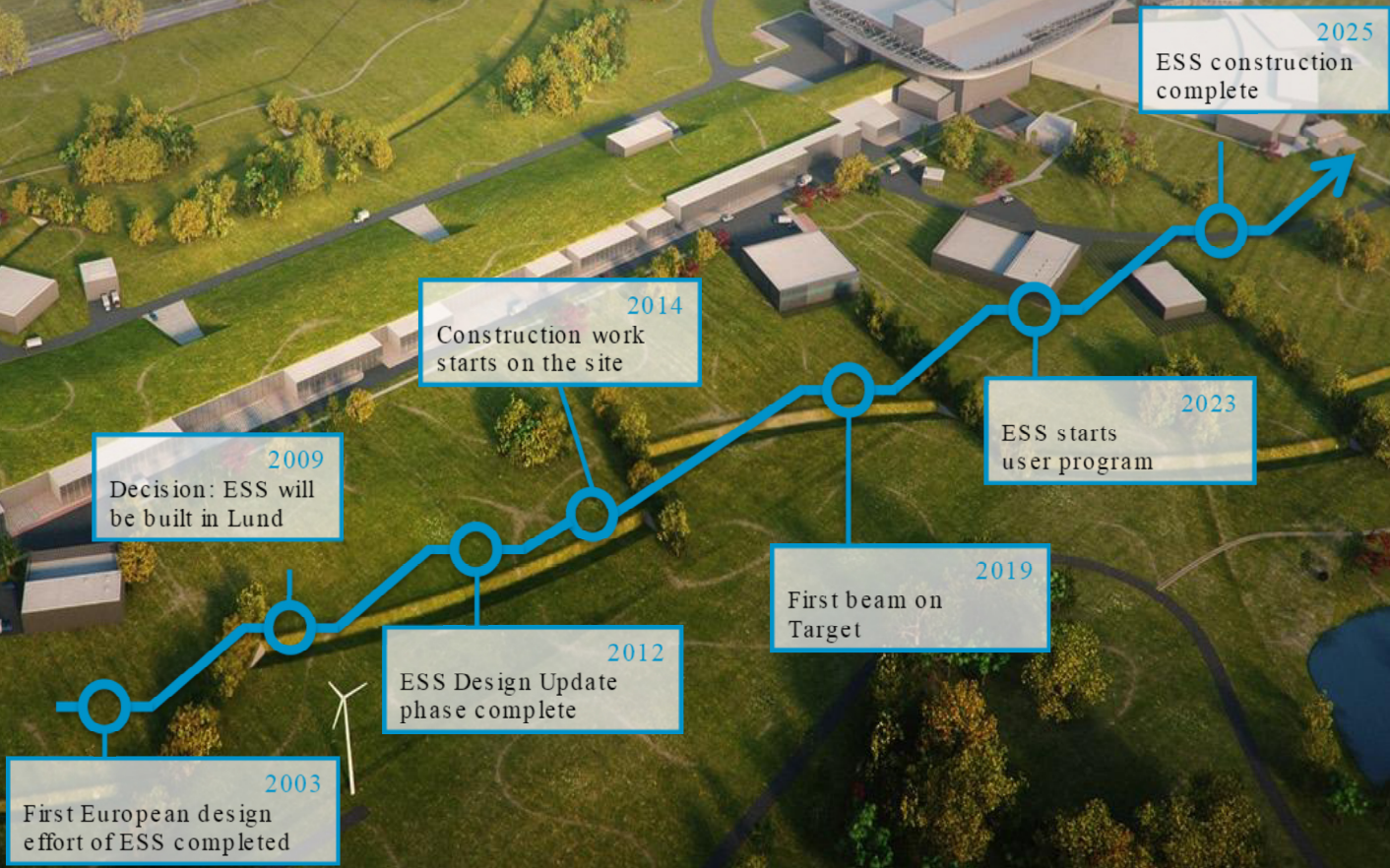
XRD
(1.1Å)



Neutron
(1.9Å)



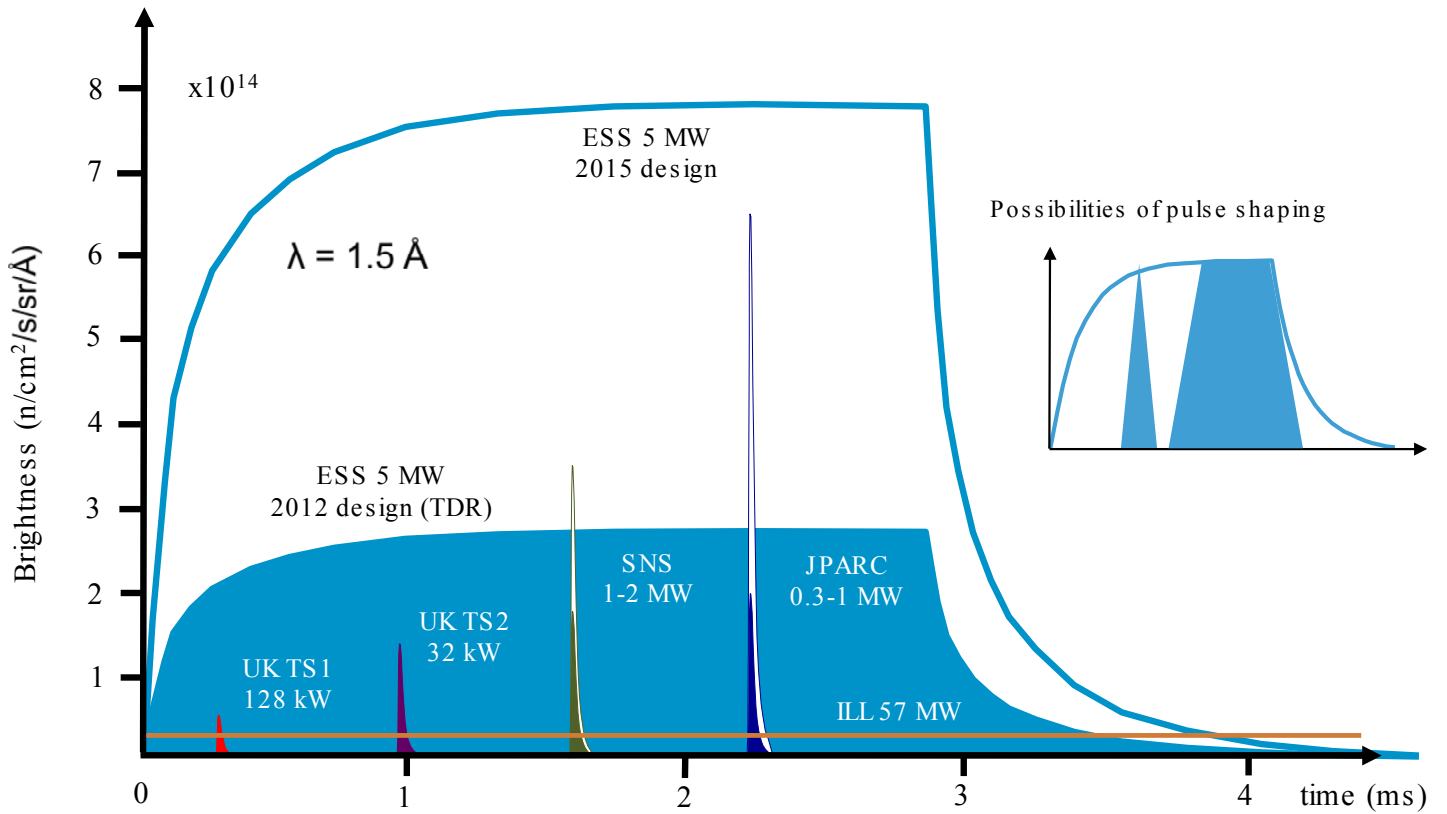
Journey to deliver the world's leading facility for research using neutrons



ESS design



Long-pulse performance



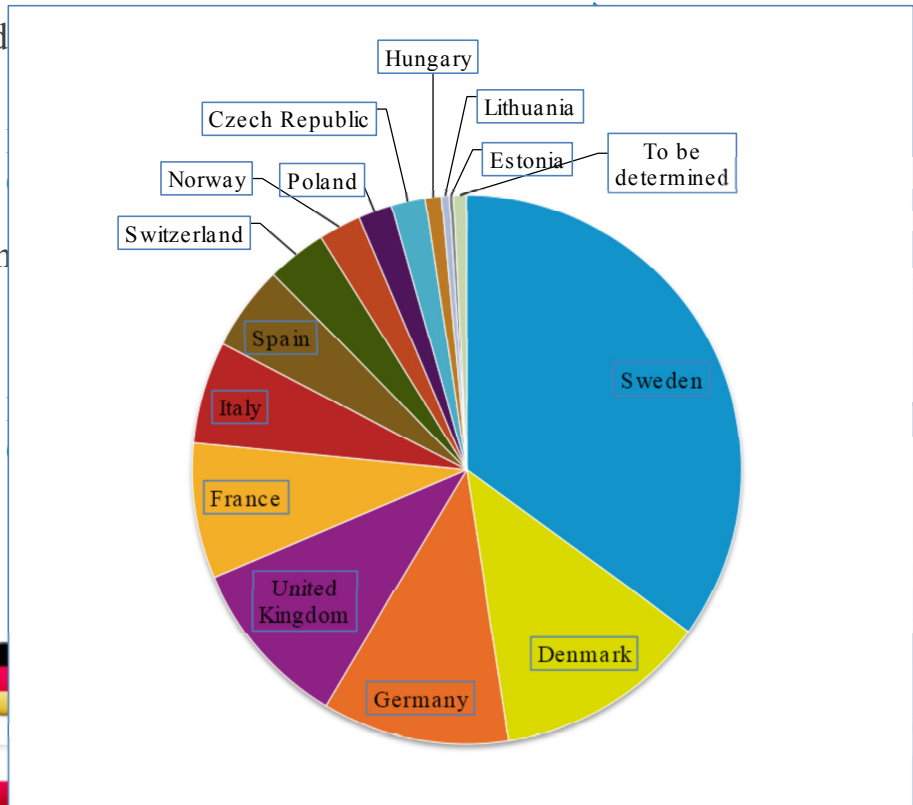
Financing includes cash and deliverables

Host Countries of Sweden

Construction 47.5%
Operations 15%

Non Host Member Countries

Construction 52.5%
Operations 85%



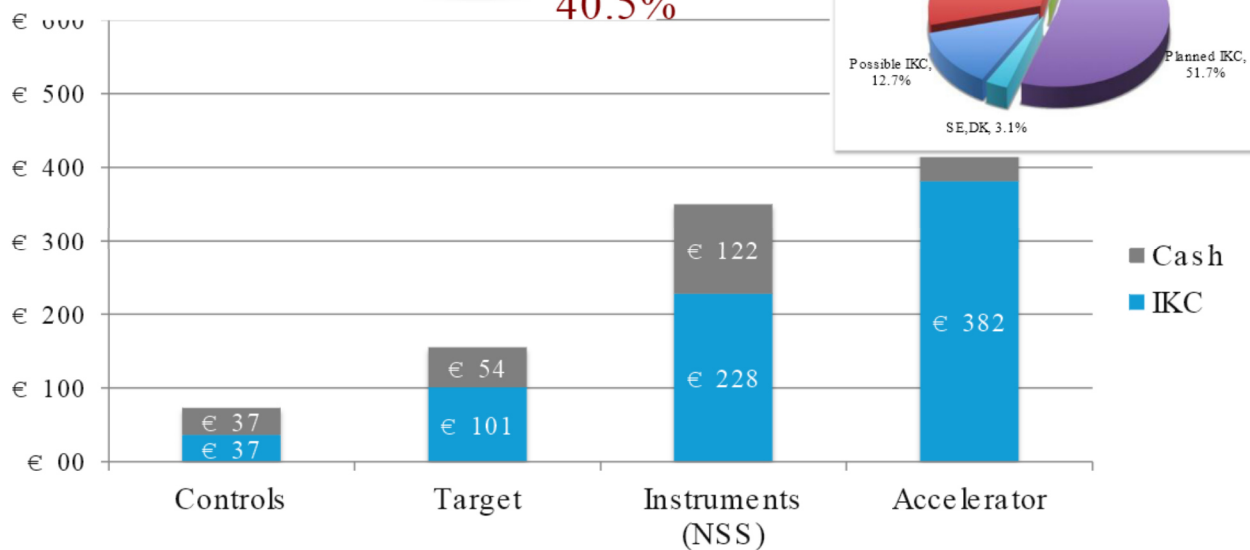
ESS: A European collaboration project



Aarhus University
Atomki - Institute for Nuclear Research

Institute for Energy Research (IFE)
Institut Laue-Langevin (ILL)

Construction cost: € 1.84 Billion
In-kind: € 747.5 Million
40.5%



Accelerator Division – Scope Accelerator Technical performances

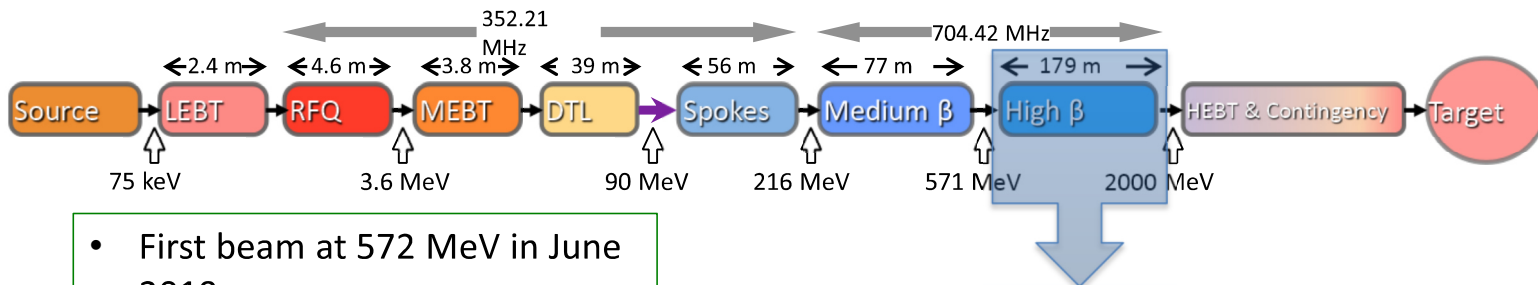
Design Drivers:

- High Average Beam Power
5 MW
- High Peak Beam Power
125 MW
- High Availability



Key parameters:

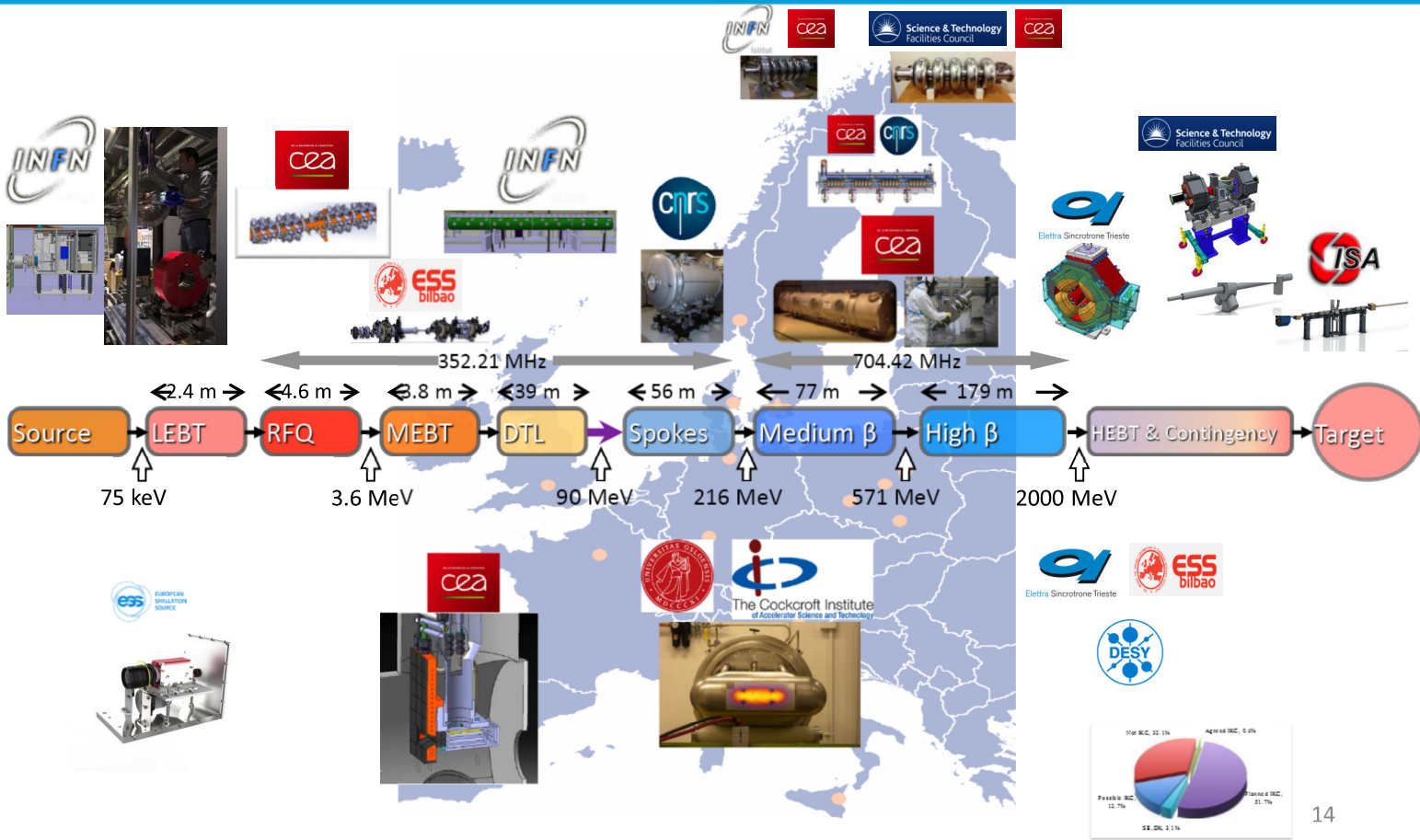
- 2.86 ms pulses
- 2 GeV
- 62.5 mA peak
- 14 Hz
- Protons (H⁺)
- Low losses
- Minimize energy use
- Flexible design for mitigation and future upgrades



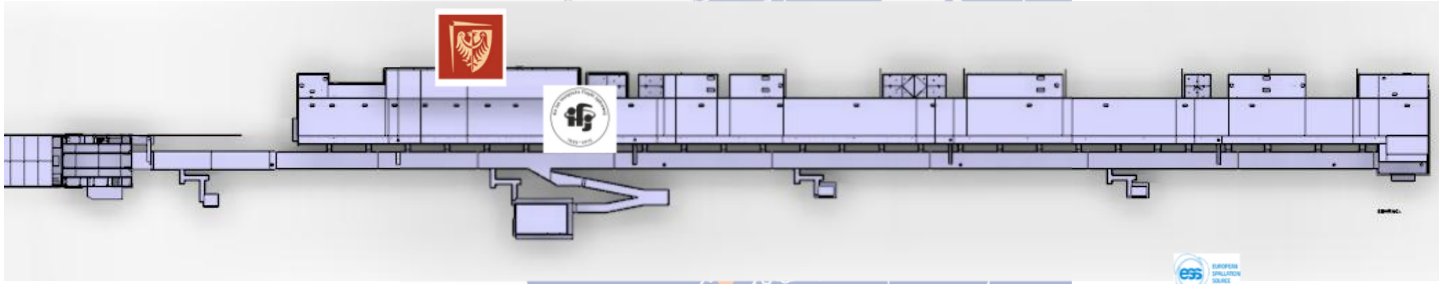
- First beam at 572 MeV in June 2019
- 5 MW capacity for 2023

RF sources for HB part is the scope contingency for accelerator

Accelerator Collaboration - Accelerator



Accelerator Collaboration – RF and STS



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.

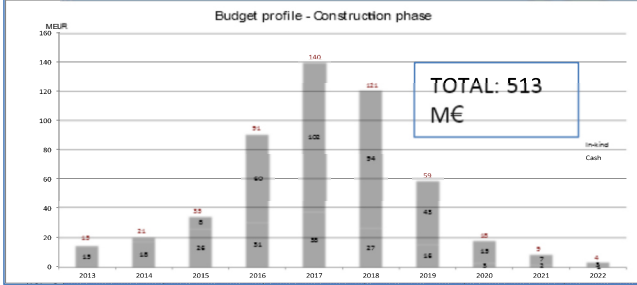
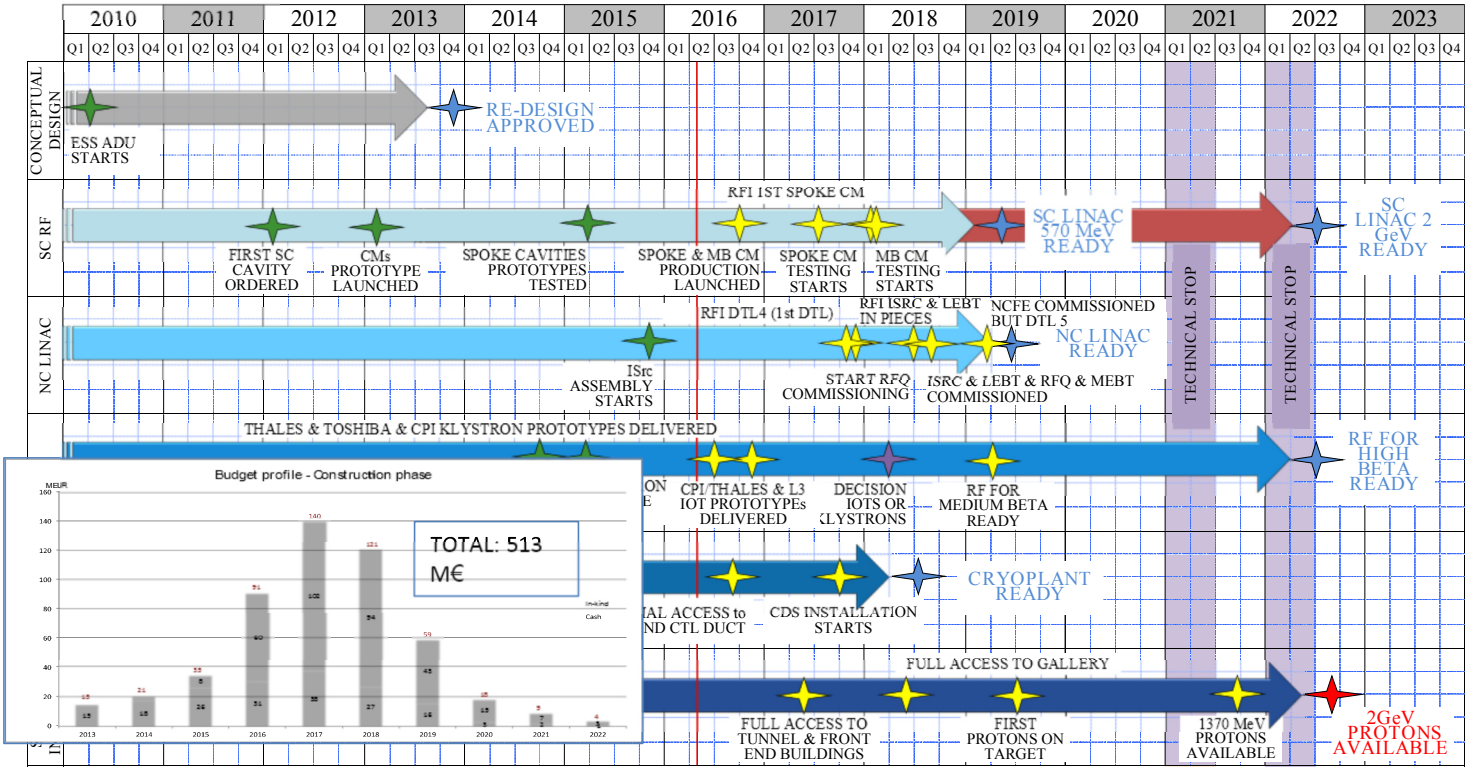
Total remaining possible IK is 65 045 k€

High Level Master Schedule (Level 1)



EUROPEAN SPALLATION SOURCE

HIGH LEVEL SCHEDULE - ESSACCELERATOR

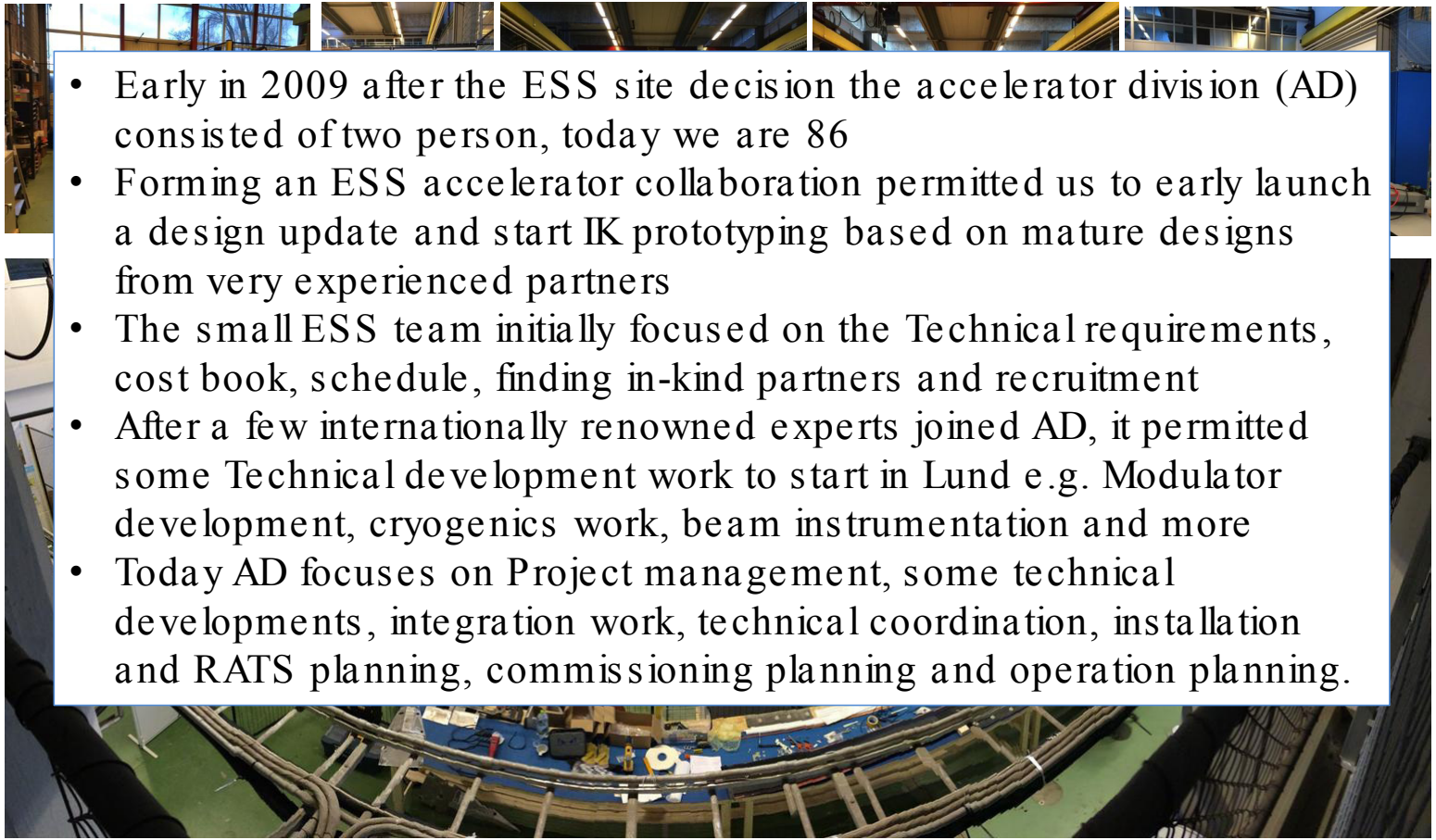


DATA EXTRACTED BY P6 PLANNING - APRIL 2016

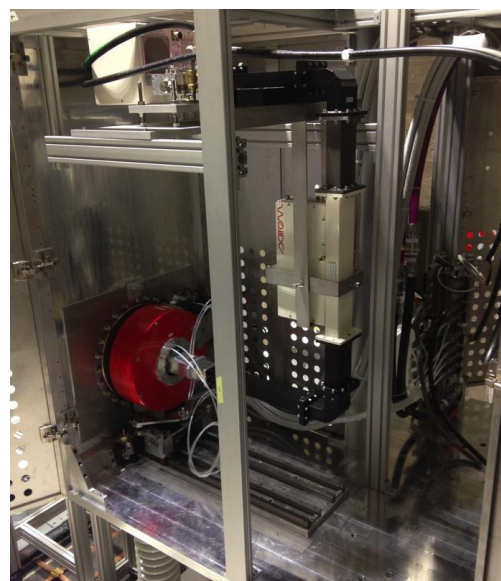
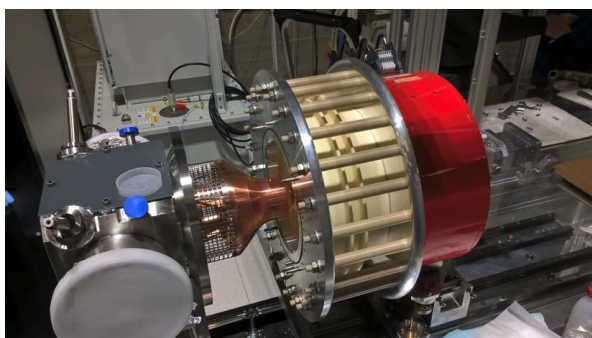
PREPARED BY WP LEADERS & L. LARI, L. GUNNARSSON
 CHECKED BY J. WEISEND
 APPROVED BY M. LINDROOS

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.

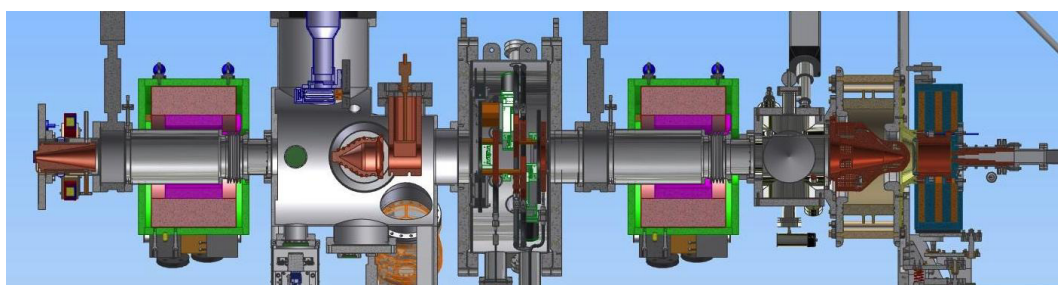


Microwave Discharge Ion Source (MDIS)



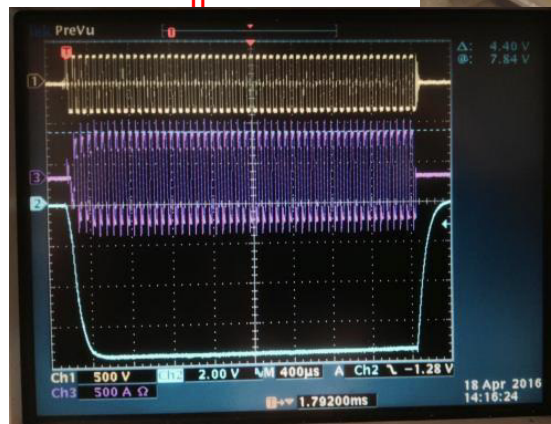
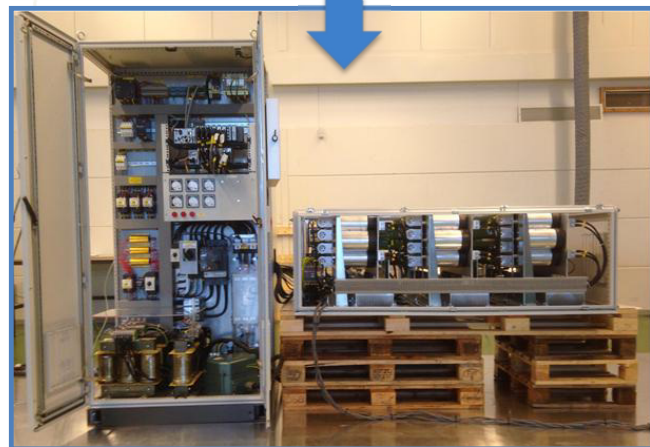
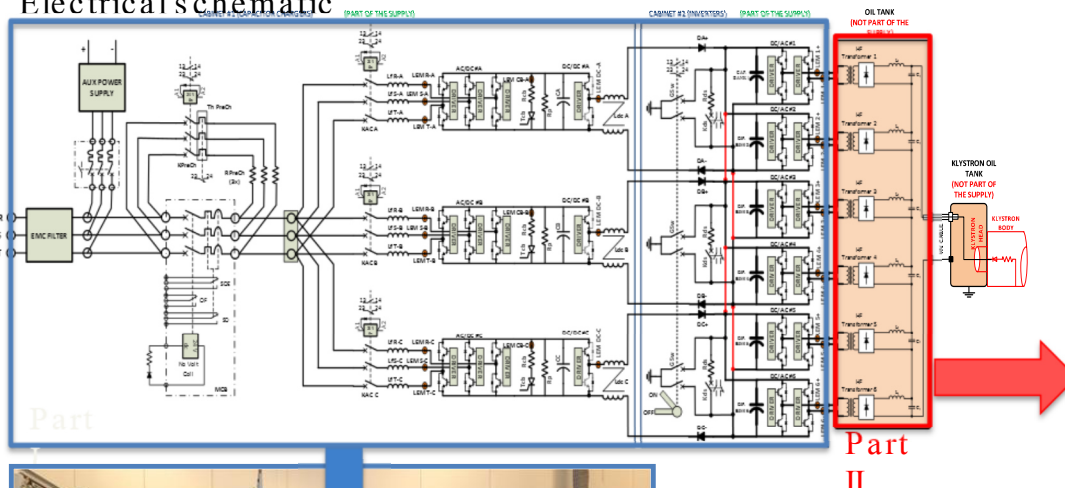
Parameters	Value
Nominal proton peak current	74 mA
Proton fraction	> 80 %
Stable operation current range	60-74 mA
Current stability(over 50us period)	± 2 %
Pulse to pulse variation	± 3.5 %
Beam Energy	75 keV (±0.01)
Distance between pulses	1 Hz< f <14 Hz
Restart after vacuum break	<32 h
Restart after cold start	<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	$\alpha = 1.02 \pm 20\%$
Twiss parameter: β	$\beta = 0.11 \pm 10\%$
Rise and fall time	<20 us
Maximum LEBT pressure	6e-5 mbar



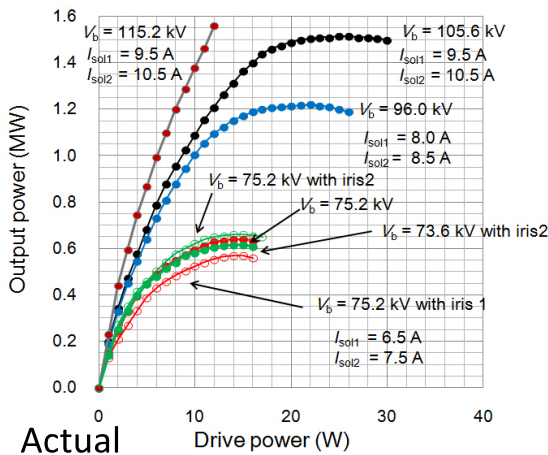
Modulator SML proto status March 2016

Electrical schematic

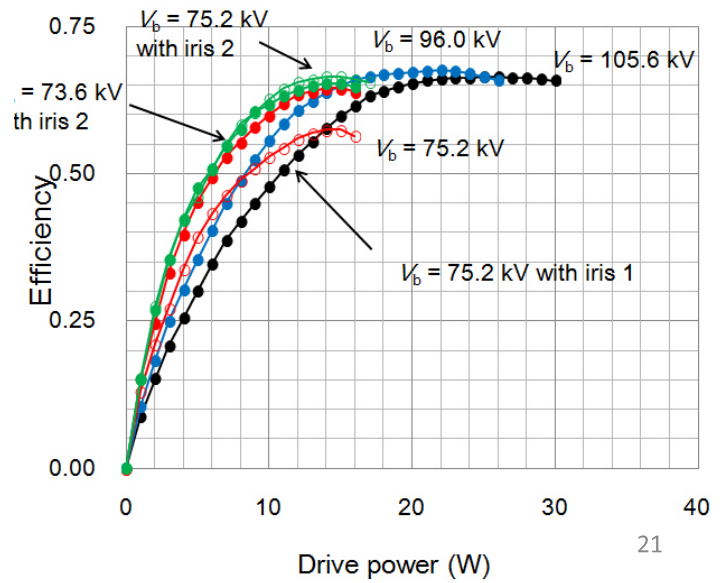


90 kV operation
Closed loop

- 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



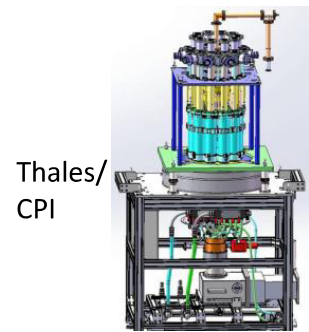
L3: Output cavity cold test



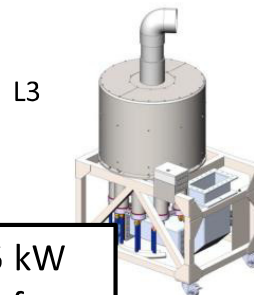
L3: Tube after bake out



L3: 15 kW driver from Tomco



Thales/
CPI



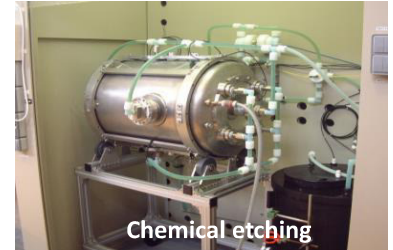
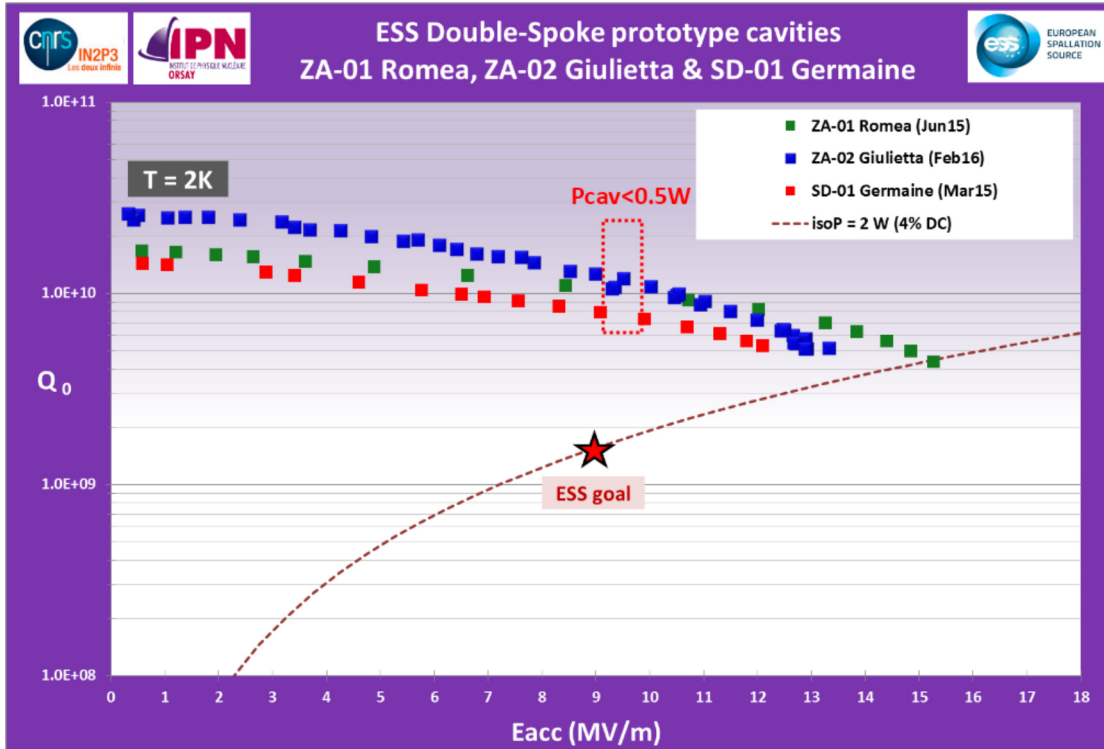
L3

Spoke Cavities design & prototype performances



Spoke cavity prototype test results (Jan15 – Feb16):

- Excellent performances, well within specifications (both on Eacc & Q₀)



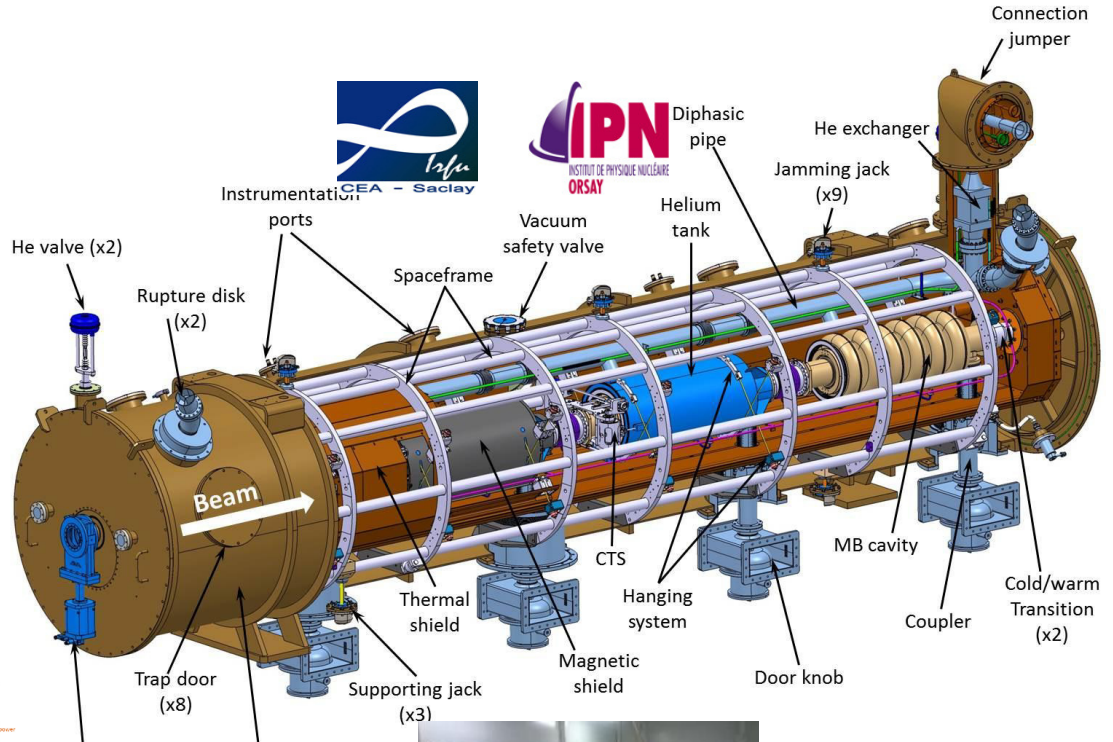
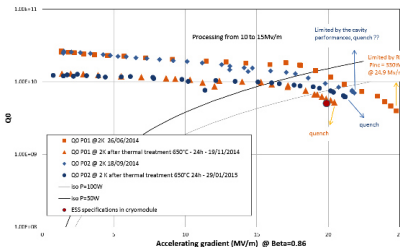
Selected technologies



Medium beta cavity prototype



High beta cavity prototype with its helium tank



Blank assembly of the spaceframe inside the vacuum tank

- 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!

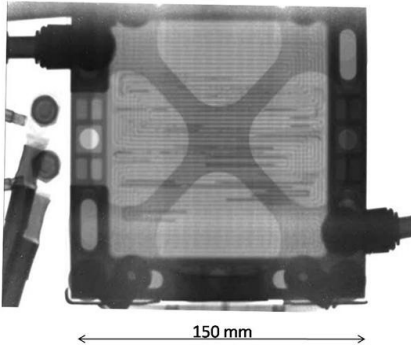


EUROPEAN
SPALLATION
SOURCE

A partnership of 17 European nations



Neutron Imaging - Examples

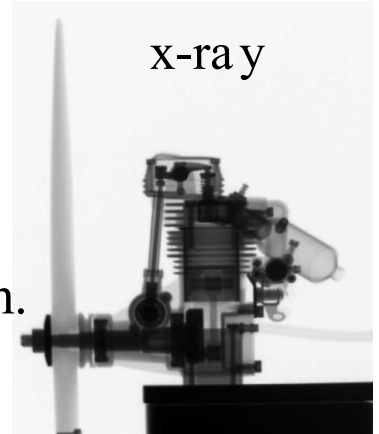


$$I = I_0 e^{-\mu \cdot d}$$

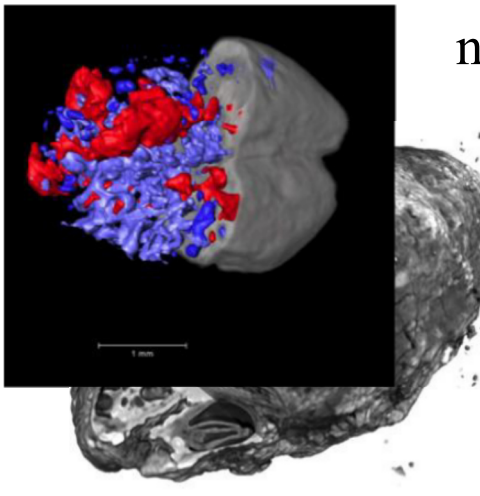
neutron μ different to x-ray

contrast hydrogen / deuterium.

not increasing with Z^2



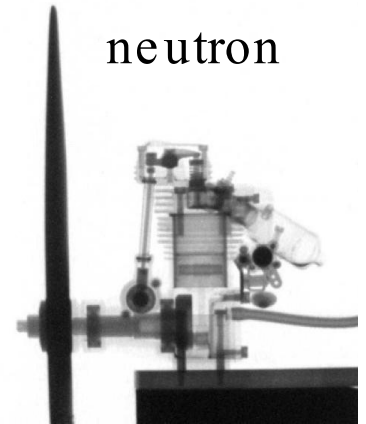
x-ray



neutron

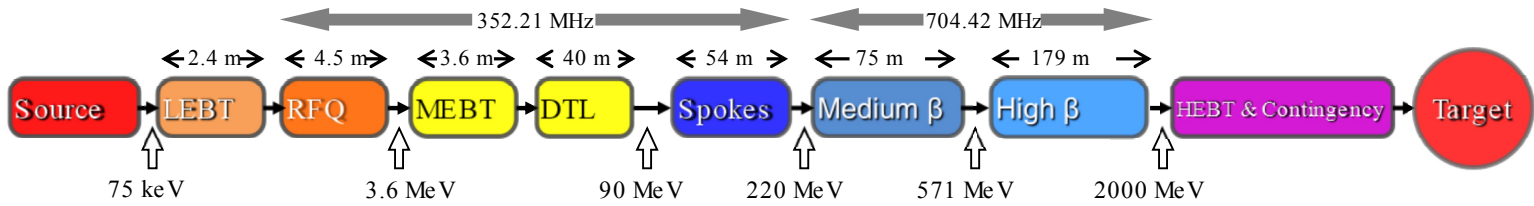


x-ray



neutron

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)	$0.5 \beta_{opt}$	~ 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

- 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 cryoplat and test stand and instruments cryoplat 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

