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The ESS Accelerator: keeping cost down but still respecting basic beam dynamics

HB 2014, East Lansing, November
2014

Mats Lindroos
Head of Accelerator



Copenhagen
Copenhagen-University
CPH Airport

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**SCIENCE
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SCANDINAVIA

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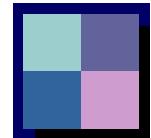
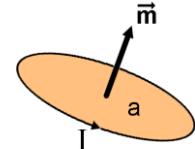
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Neutrons are beautiful !

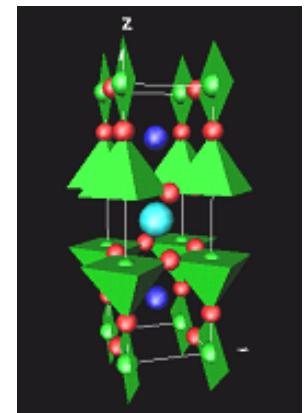
Wave Particle Magnetic moment Neutral



Diffractometers - Measure structures

- Where atoms and molecules are

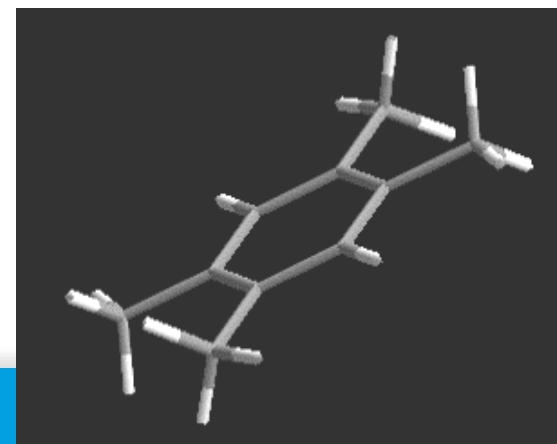
1 - 10 Ångström



Spectrometers - Measure dynamics

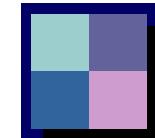
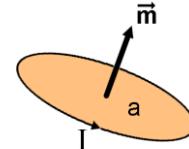
- What atoms and molecules do

1 - 80 meV

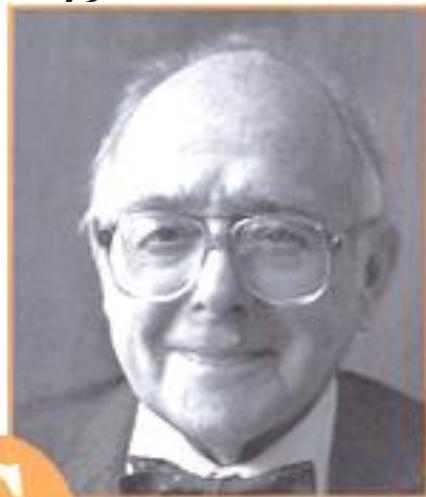


Neutrons are beautiful !

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Diffractometers - Measure structures

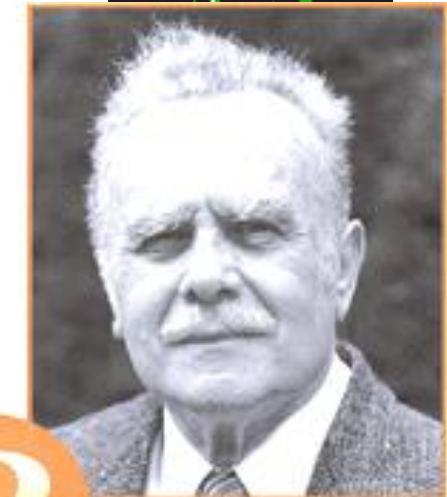


of atoms and molecules :

10 Ångström

S - Measure dynamics
of atoms and molecules do

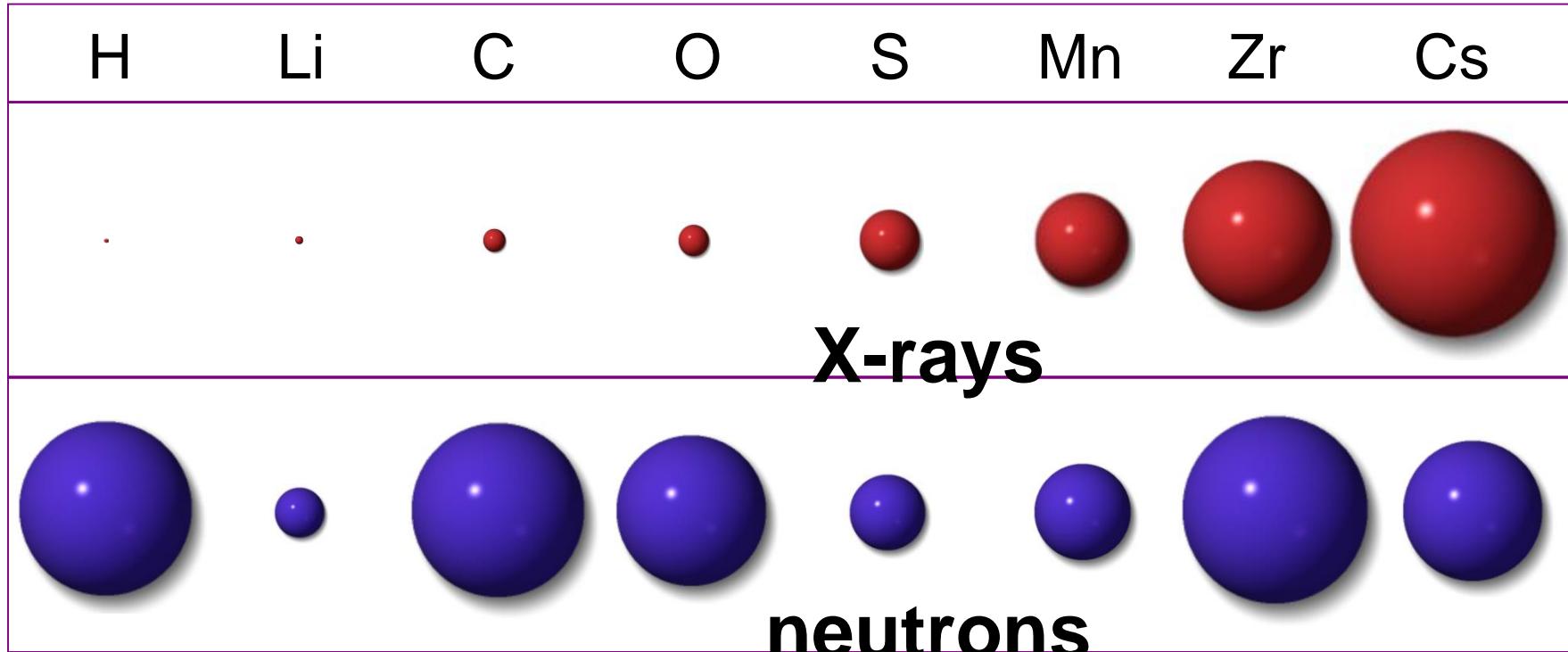
1 - 80 meV



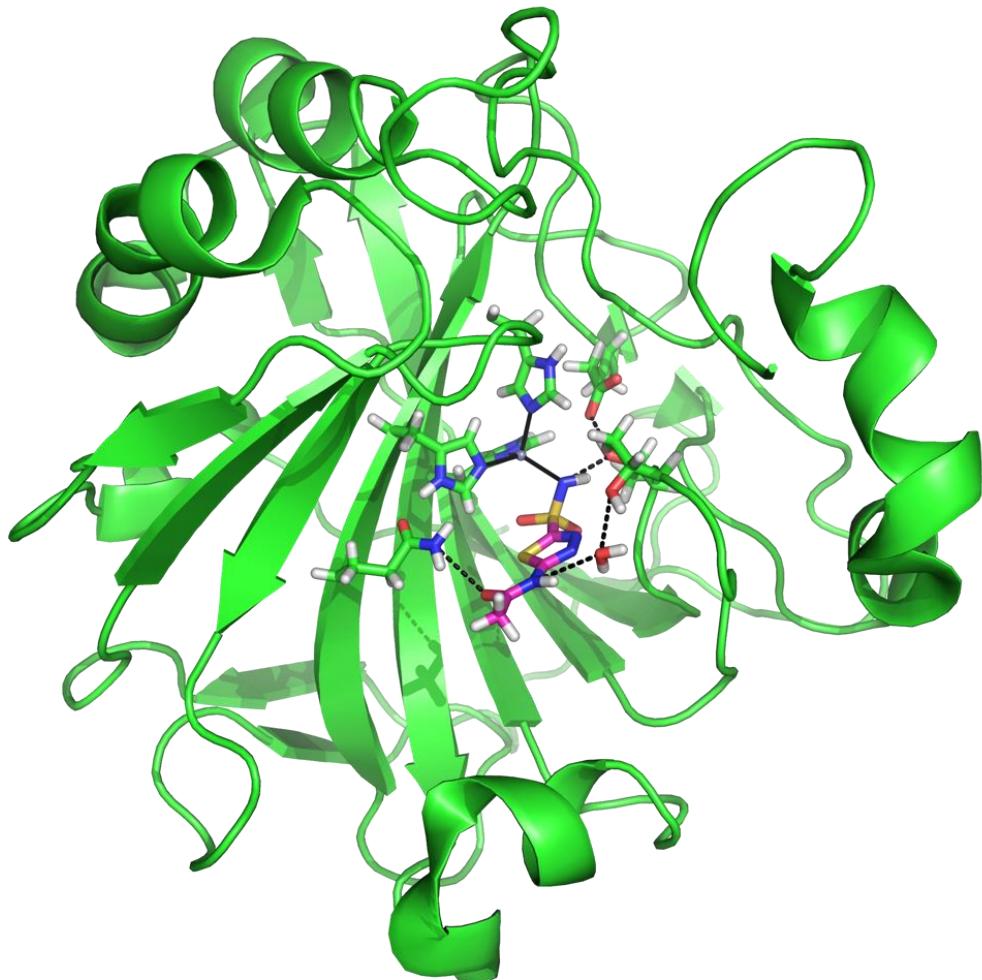
B
Bertram N. Brockhouse,
McMaster University, Hamilton,
Ontario, Canada, receives one
half of the 1994 Nobel Prize
in Physics for the development
of neutron spectroscopy.



Light and neutrons



Better drugs from detailed protein maps



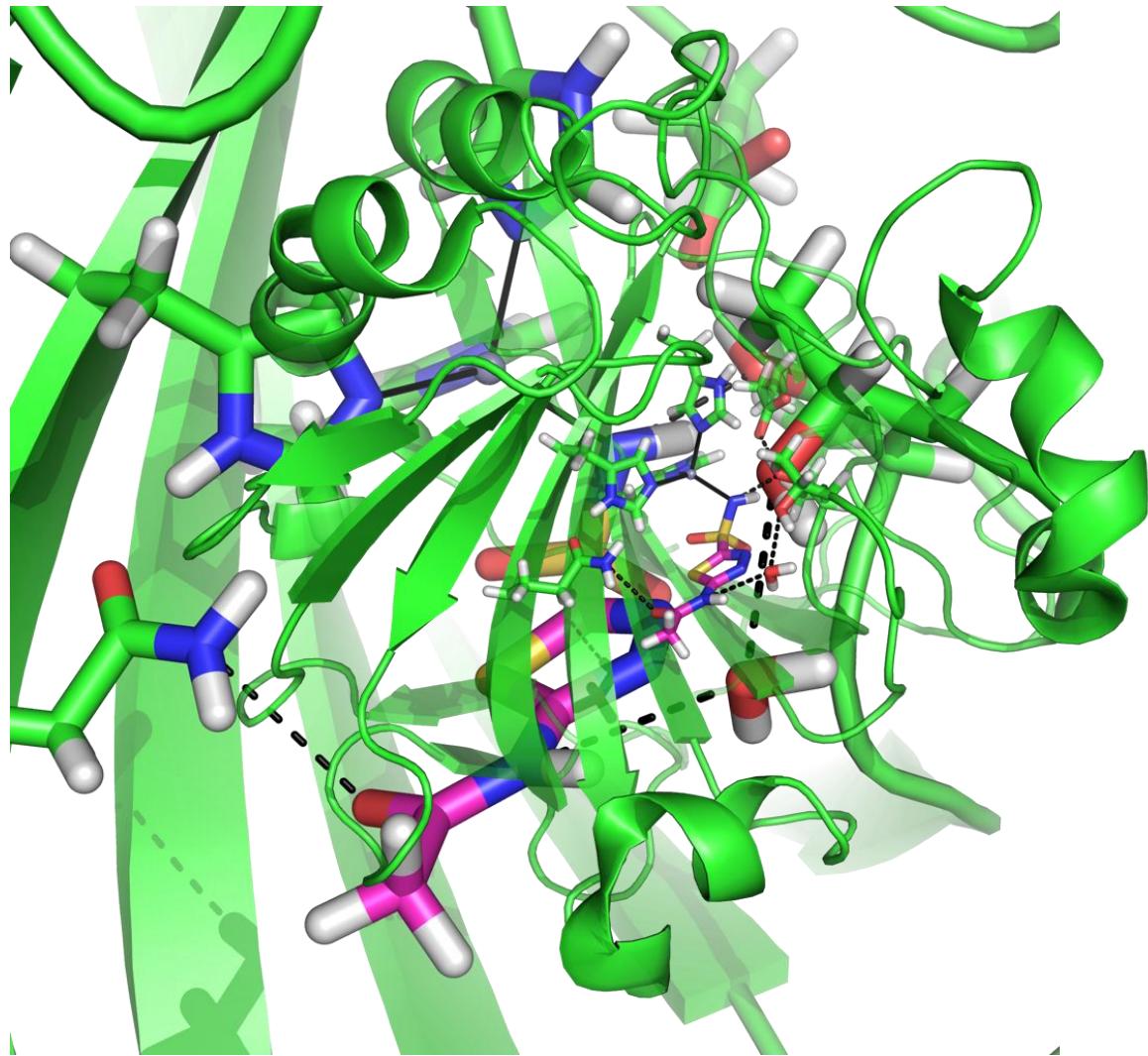
This enzyme transports CO₂ and regulates blood pH.

It is a major player in some cancers, glaucoma, obesity and high blood pressure

10^{-9} m

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Better drugs from detailed protein maps



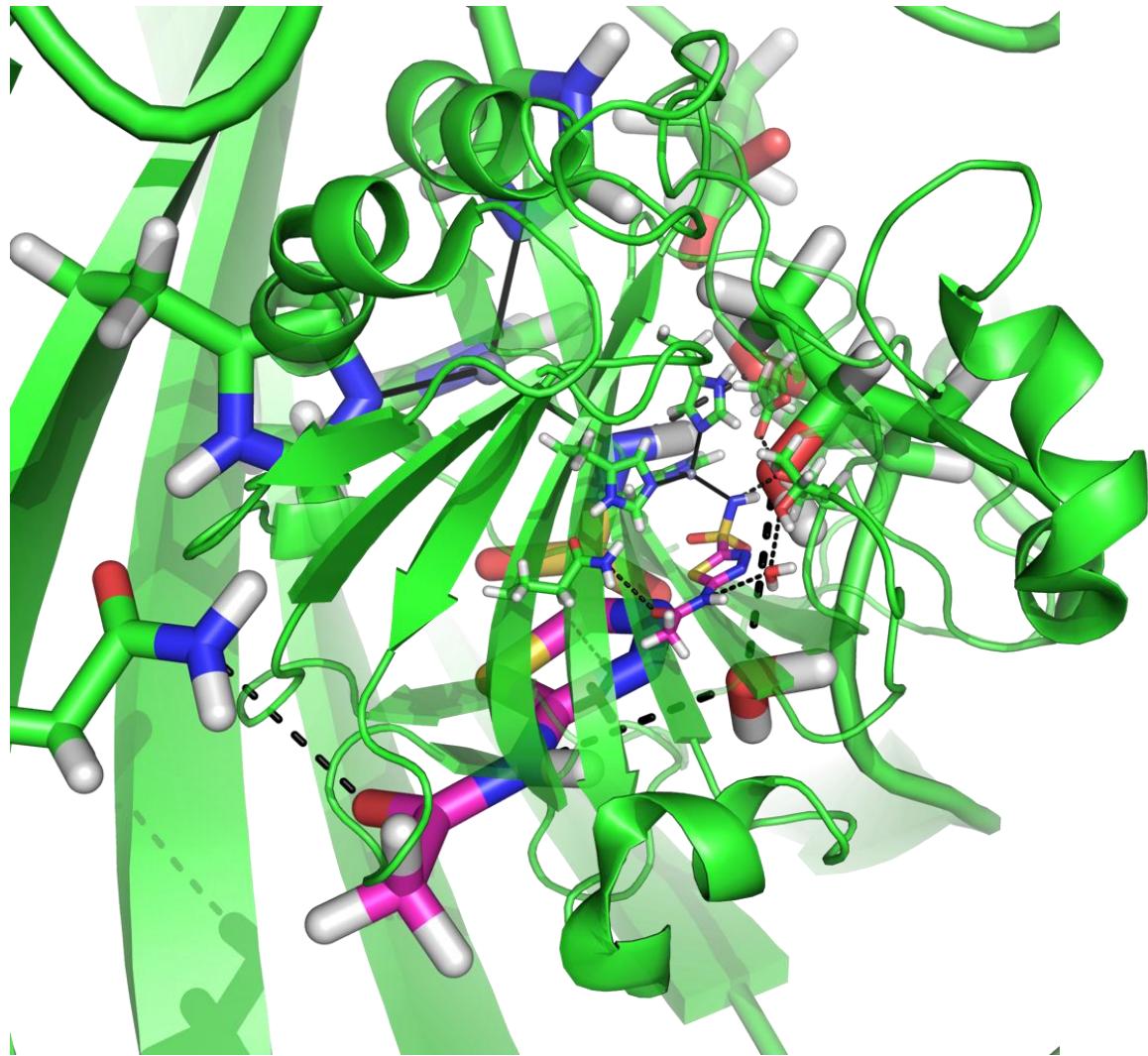
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Better drugs from detailed protein maps



This enzyme transports CO₂ and regulates blood pH.

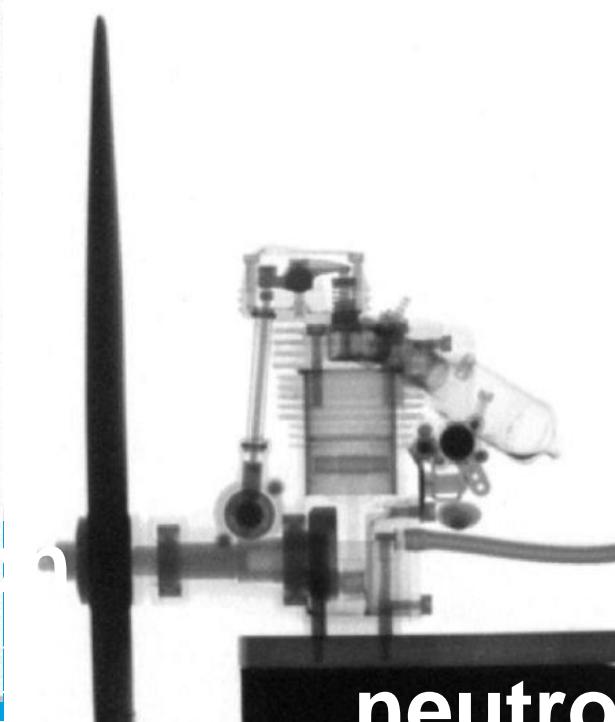
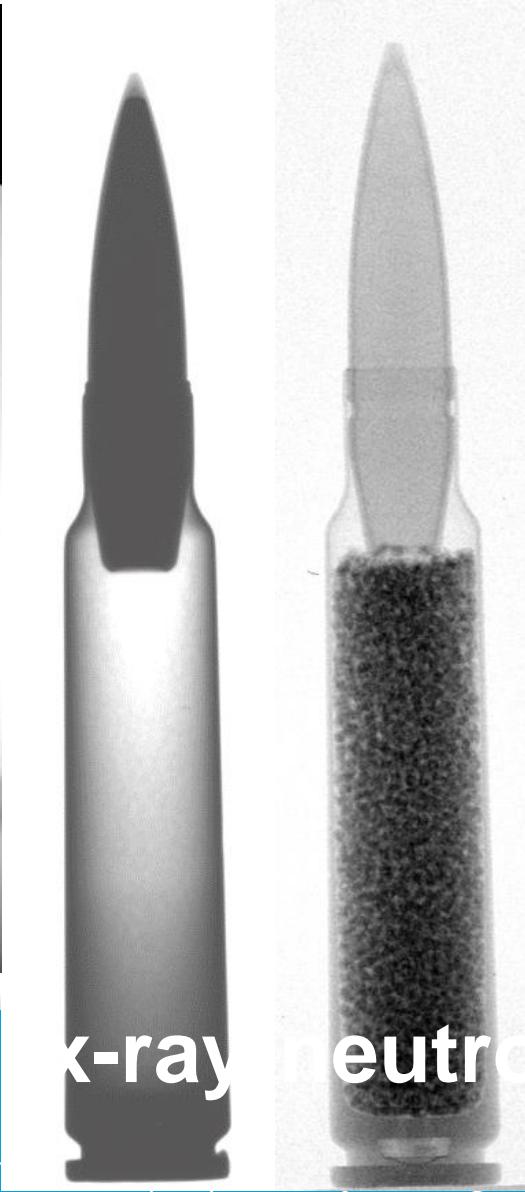
It is a major player in some cancers, glaucoma, obesity and high blood pressure

Neutron crystallography pinpoints protons and waters, showing how the drug Acetazolamide binds

10⁻⁹ m

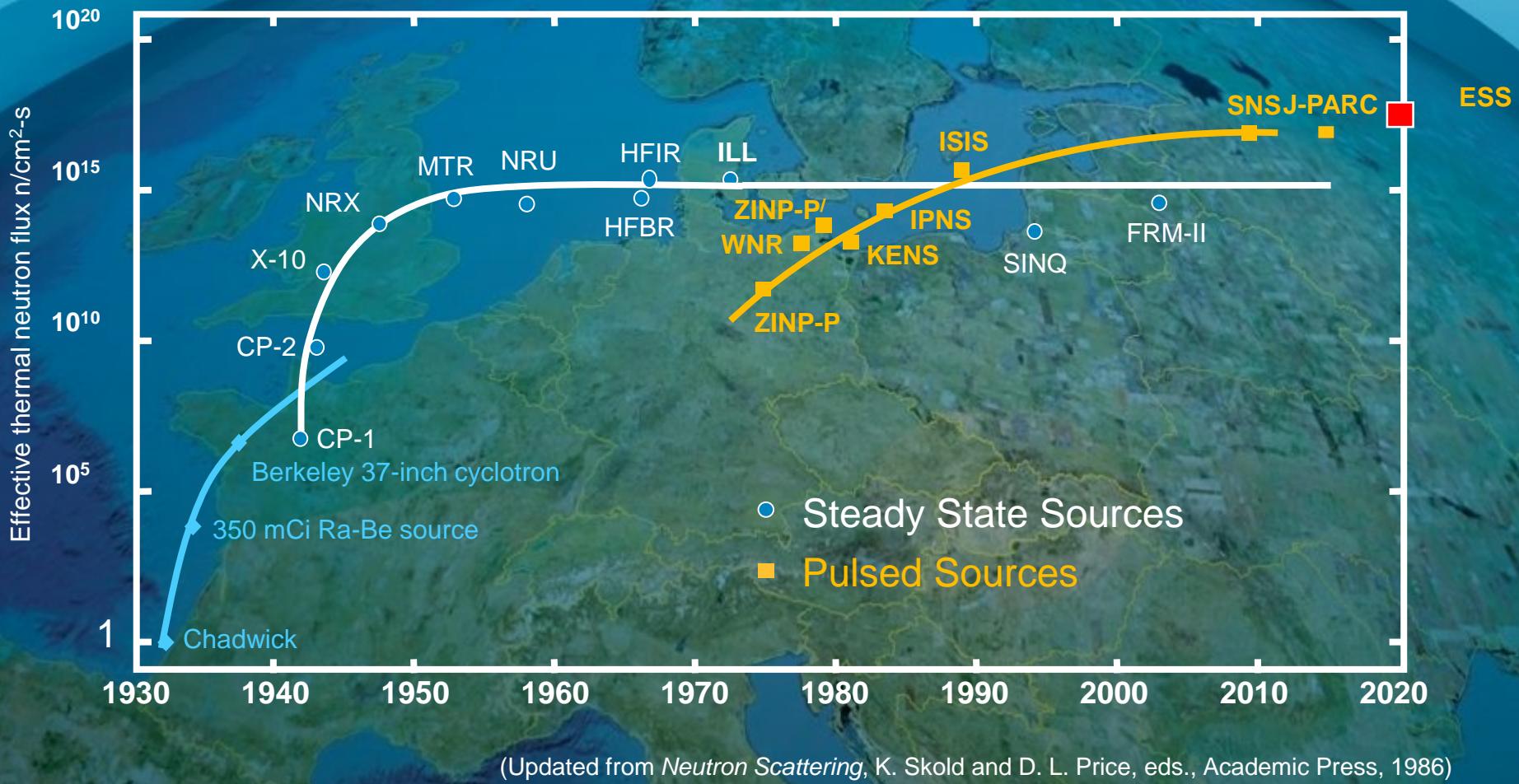
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Neutrons See the Light Elements

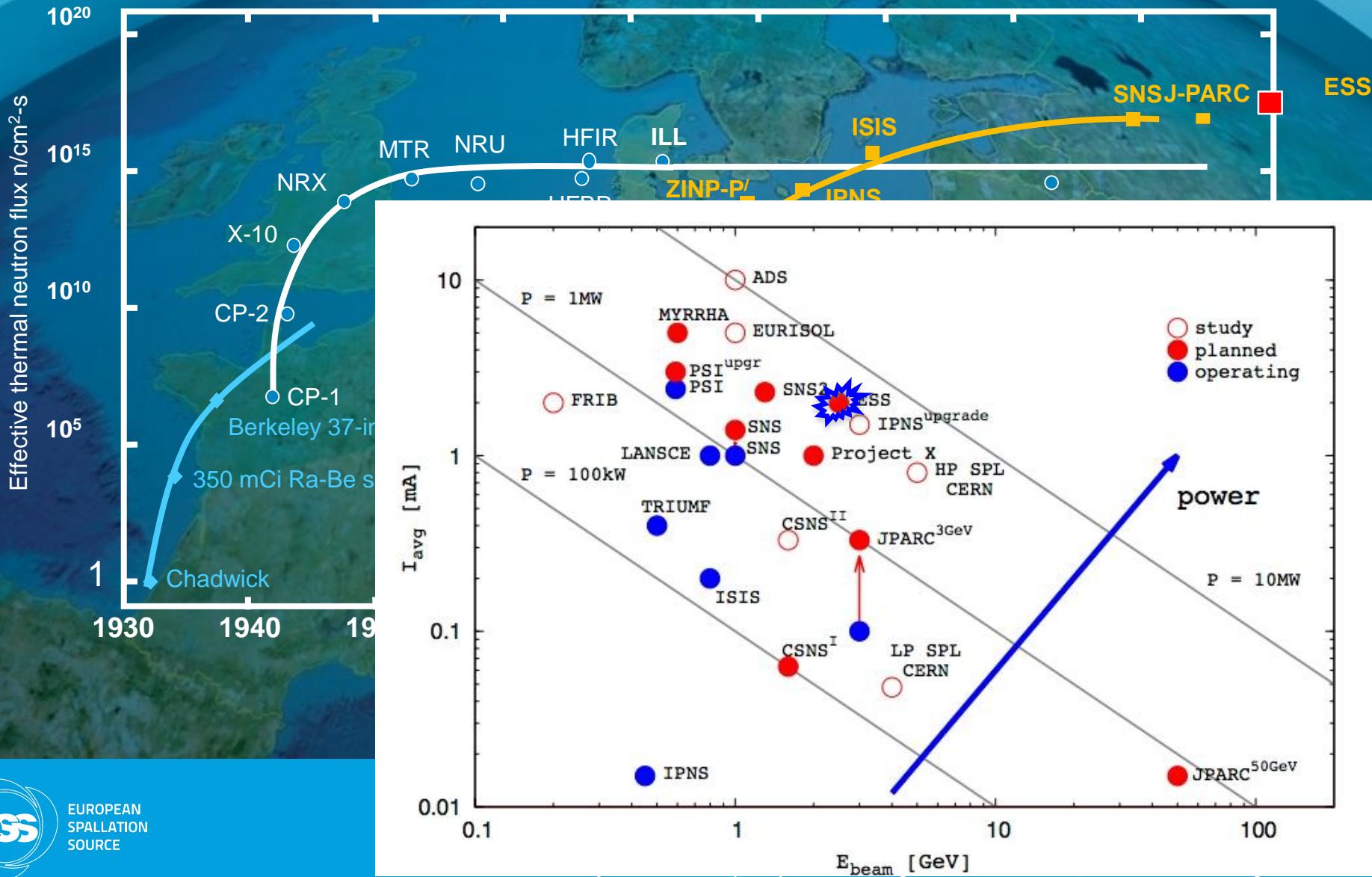


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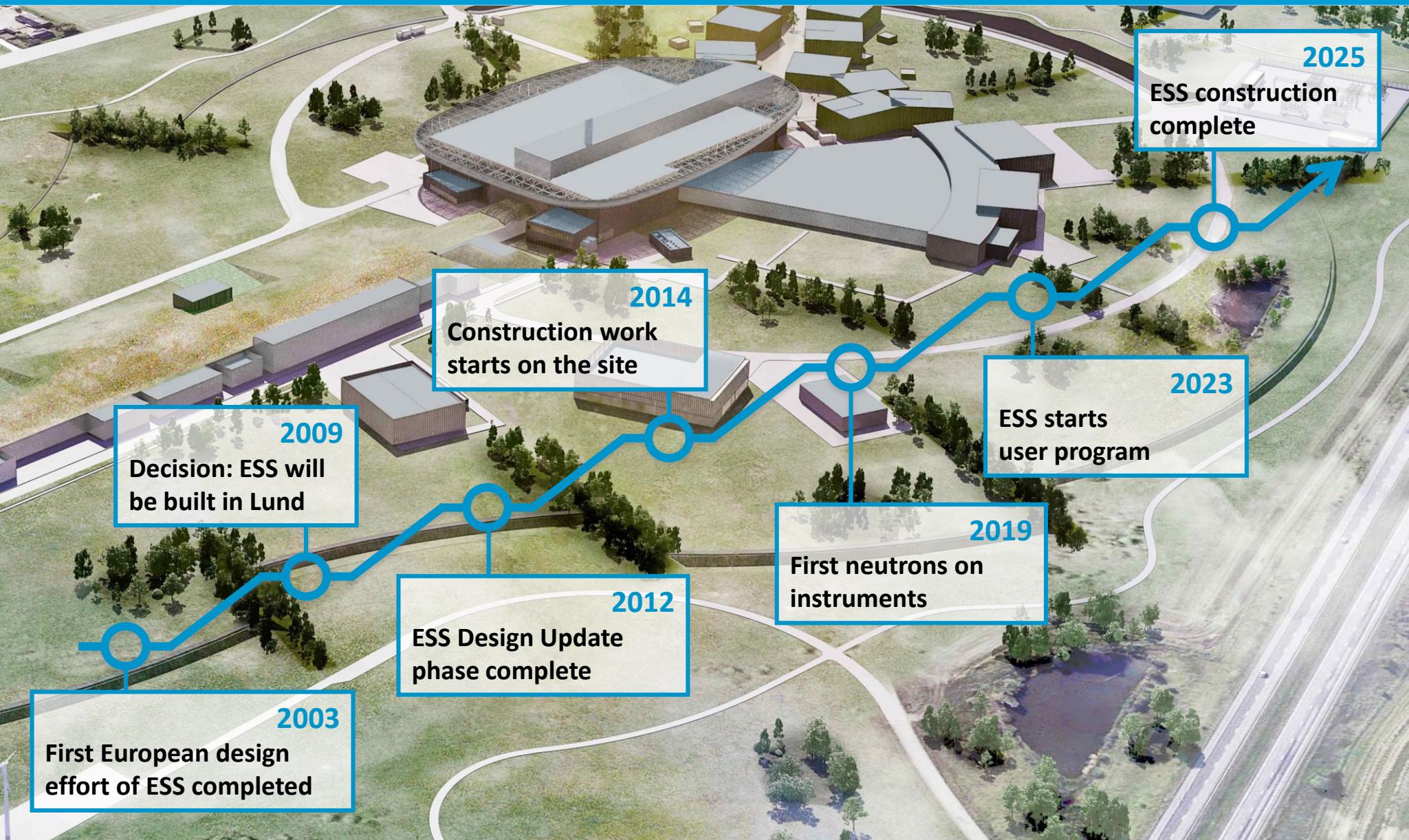
ESS - Bridging the neutron gap



ESS - Bridging the neutron gap



The road to realizing the world's leading facility for research using neutrons



Update from site



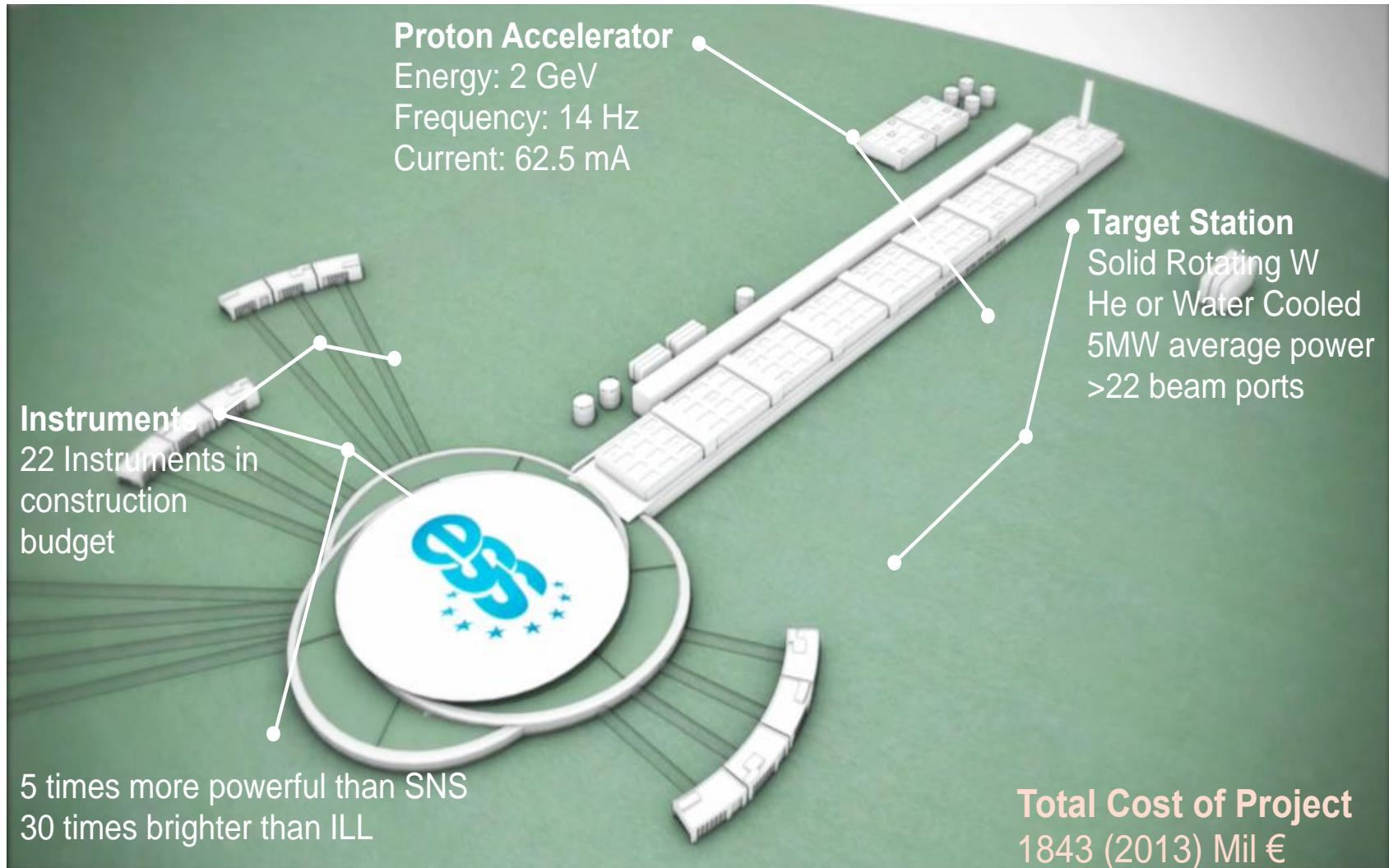
Update from site



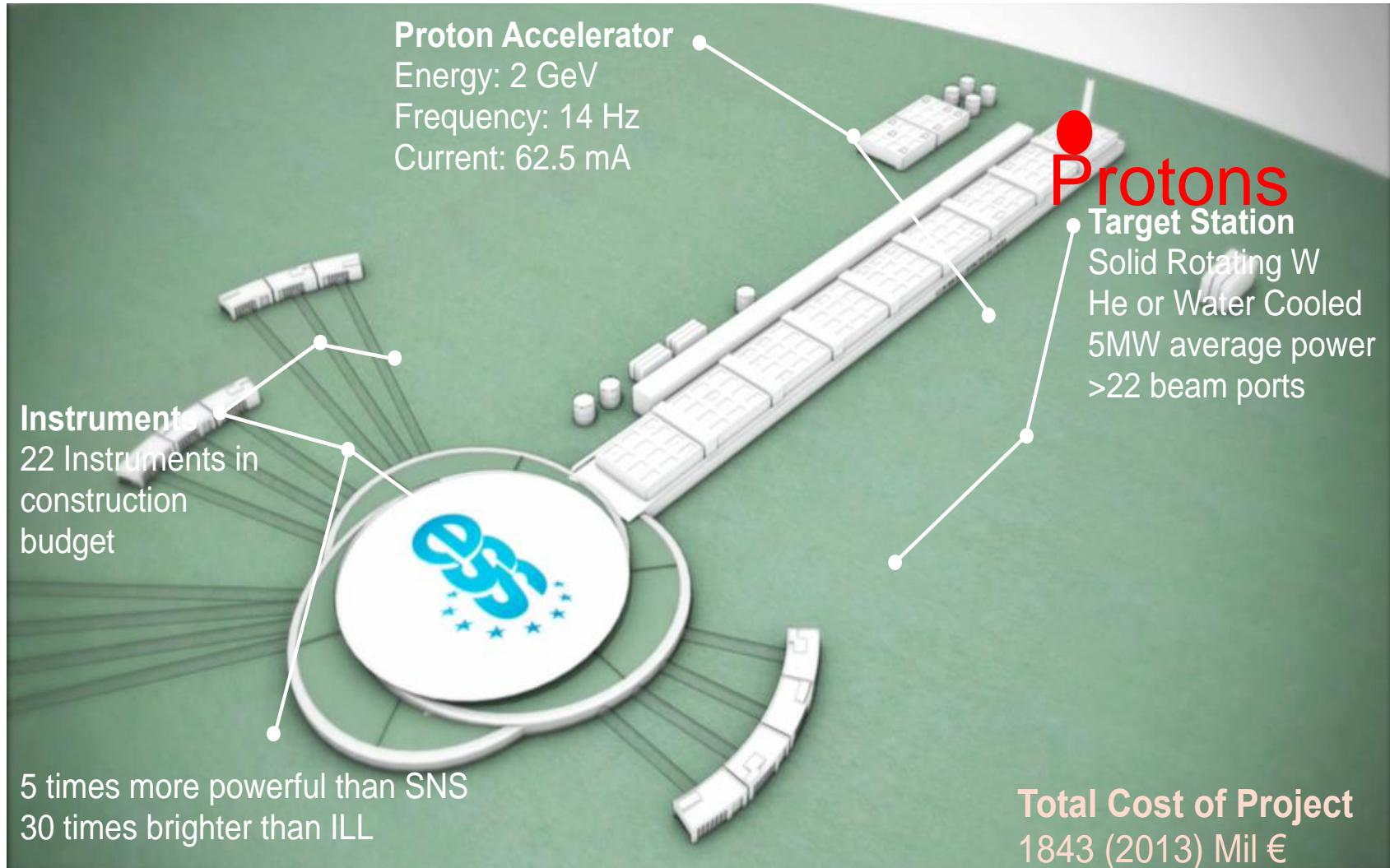
Update from site



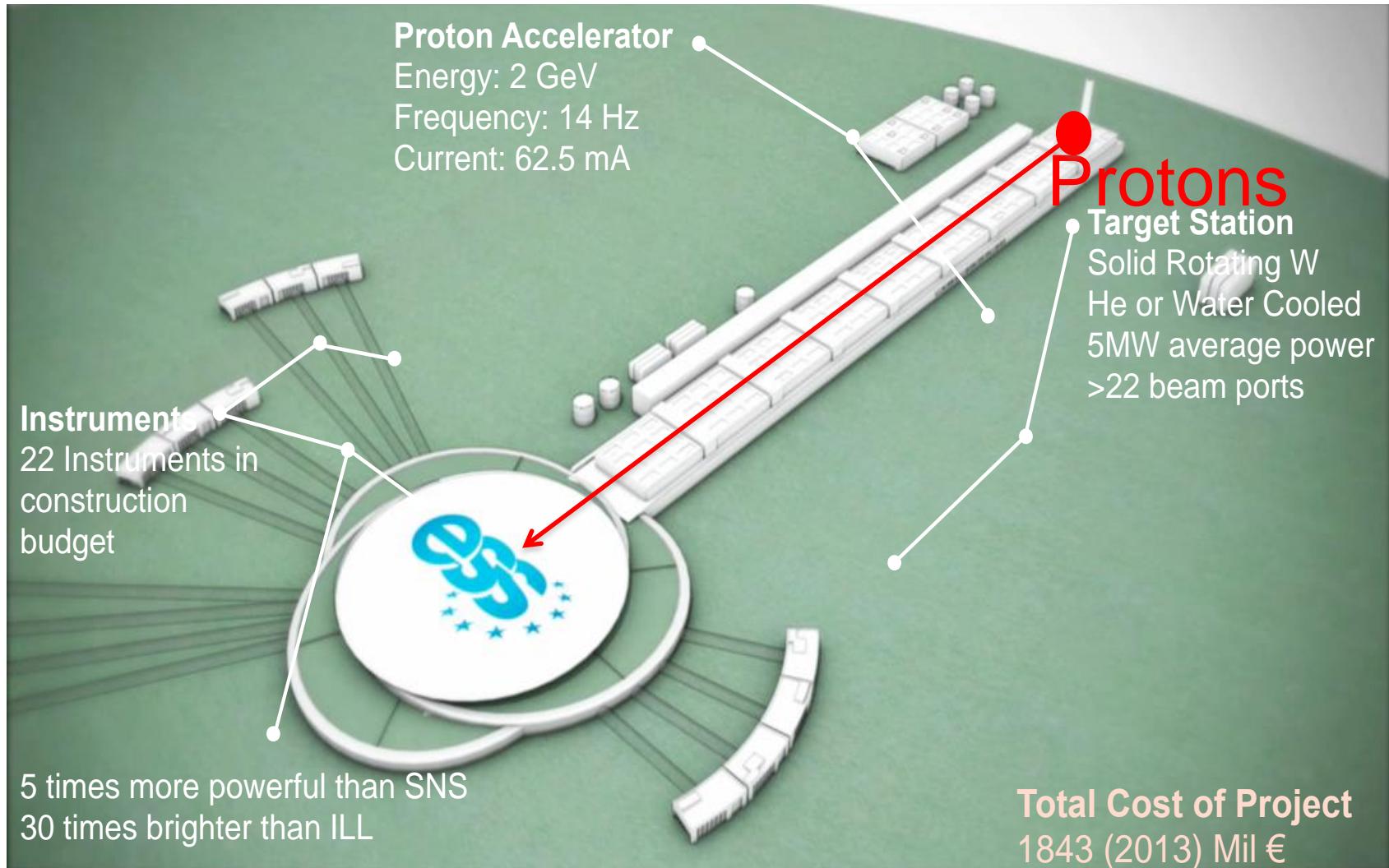
Helicopter view of ESS



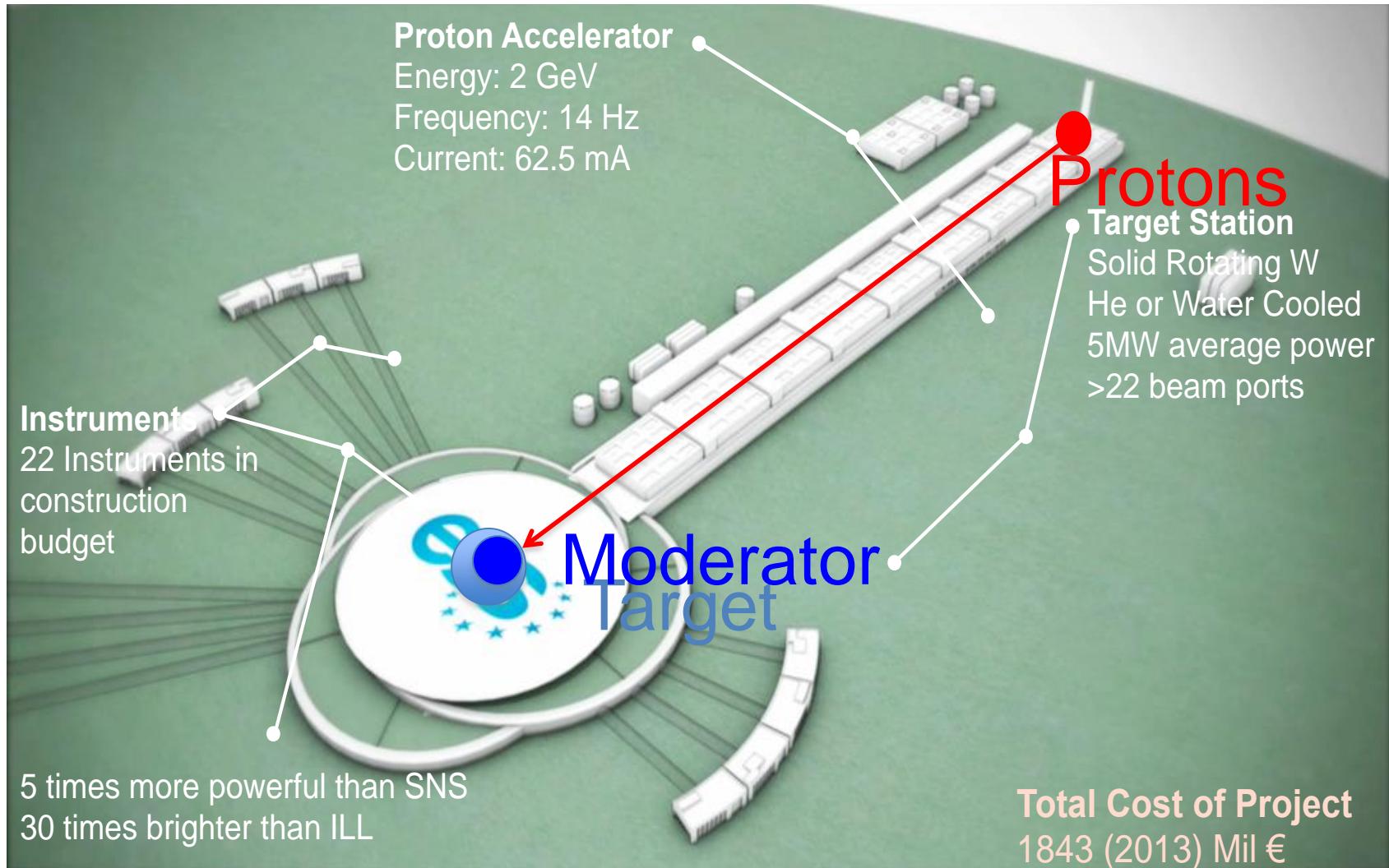
Helicopter view of ESS



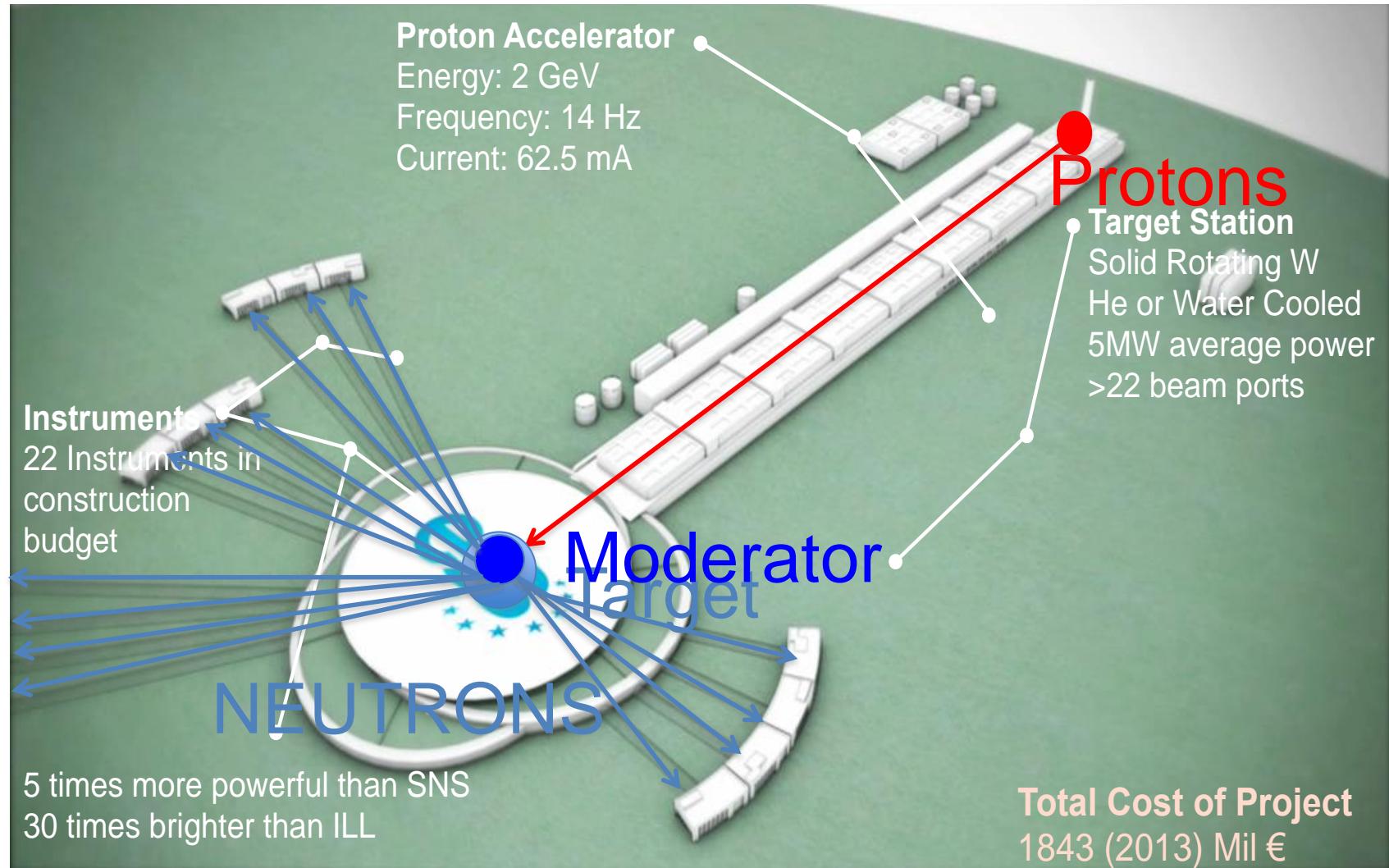
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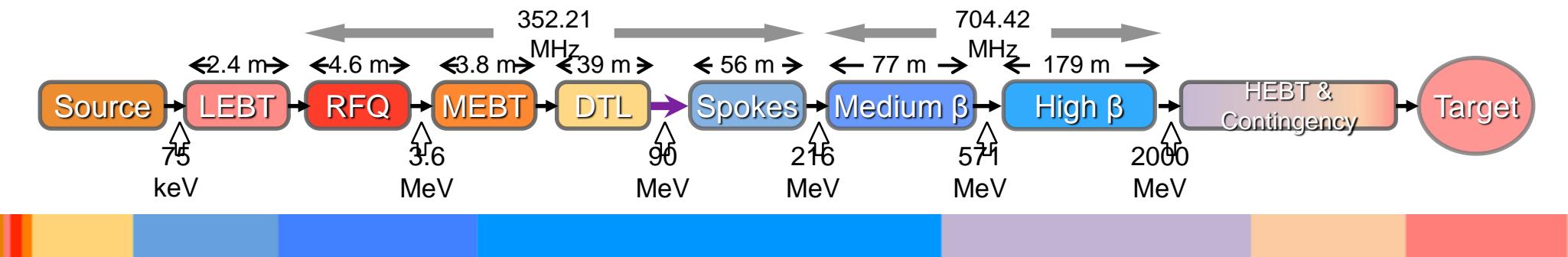
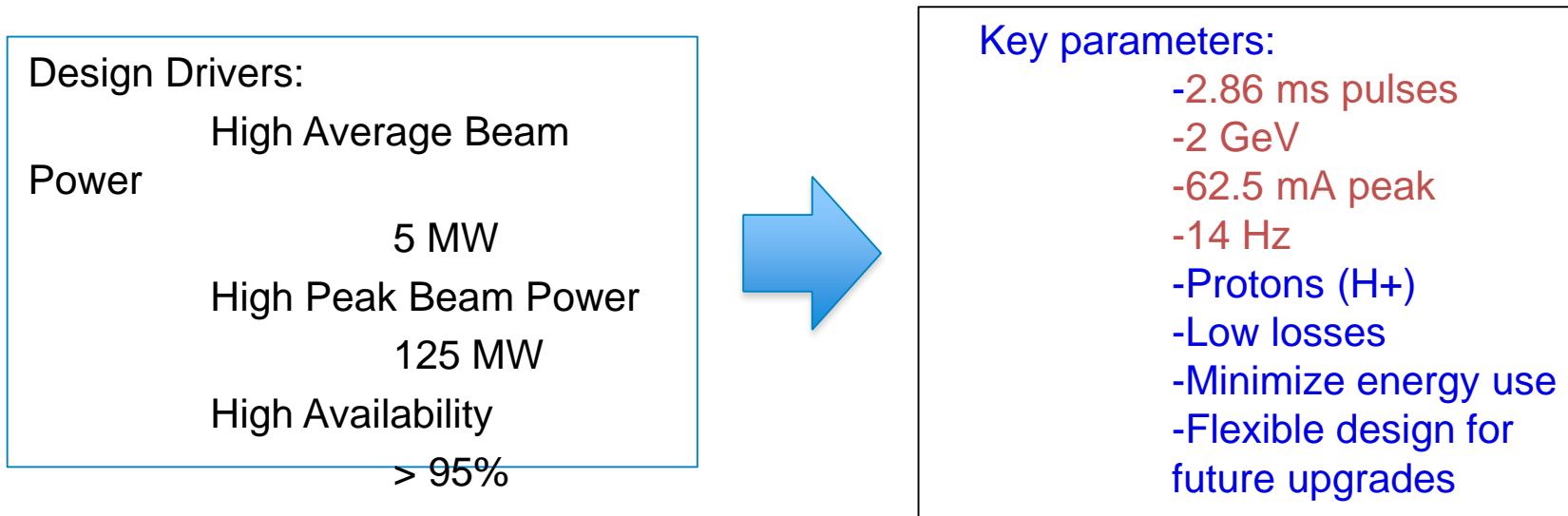
Helicopter view of ESS



Helicopter view of ESS



Build and operate a 5 MW SCRF linac

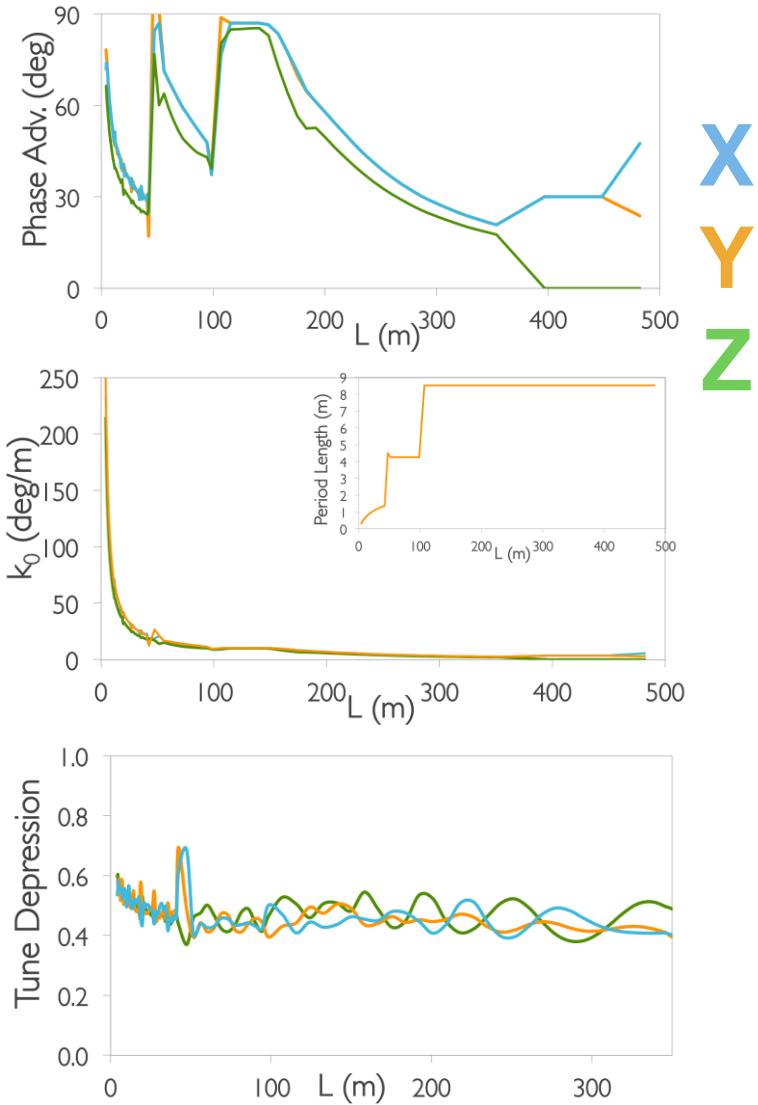


Cost Reduction Strategy

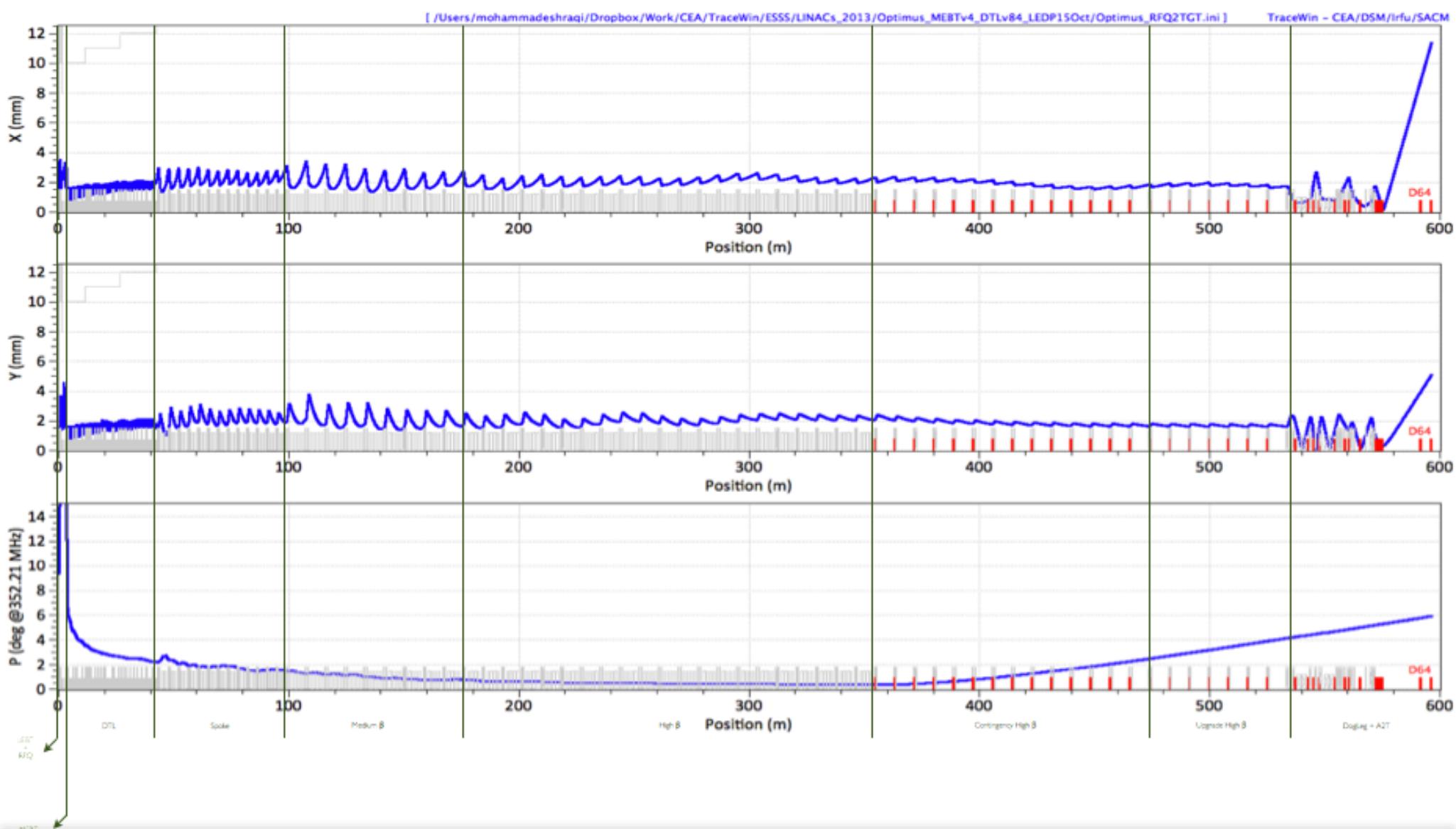
- **The cost of the elliptical cryomodules and associated RF systems are the largest cost driver in the ESS Linac**
- Reducing the number of superconducting cavities will have the largest impact on cost and design contingency
 - each cavity that is removed from the design not only removes the cost of the cavity
 - but also removes the need (and cost) for the RF power sources that feed the cavity.
- Therefore, the design contingency strategy will hold the average beam power constant while looking for avenues to minimize the number of superconducting cavities.

RULES OF THUMB

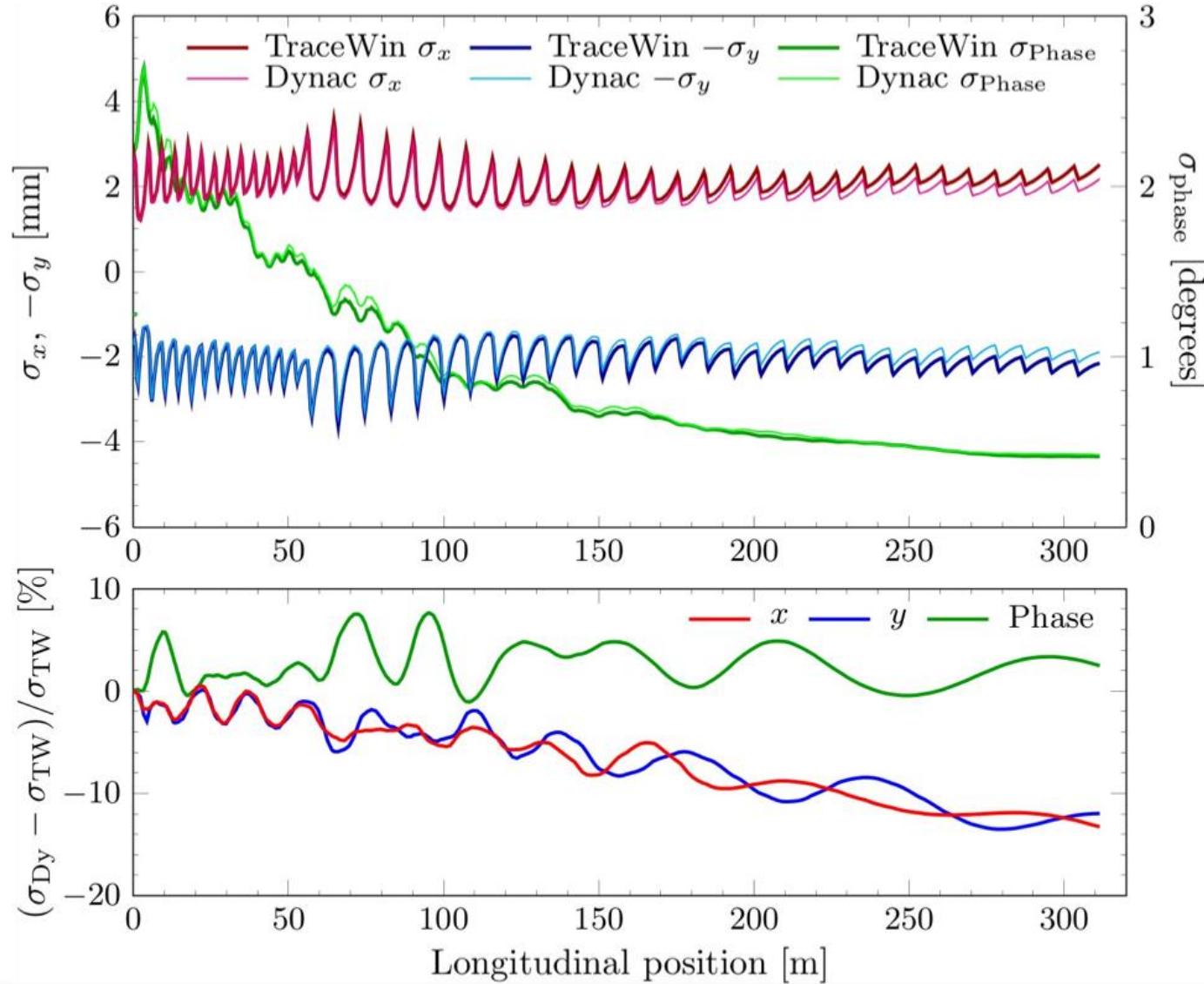
- Phase advance per period < 90 degrees
- Smooth average phase advance
- Avoiding strong tune depression



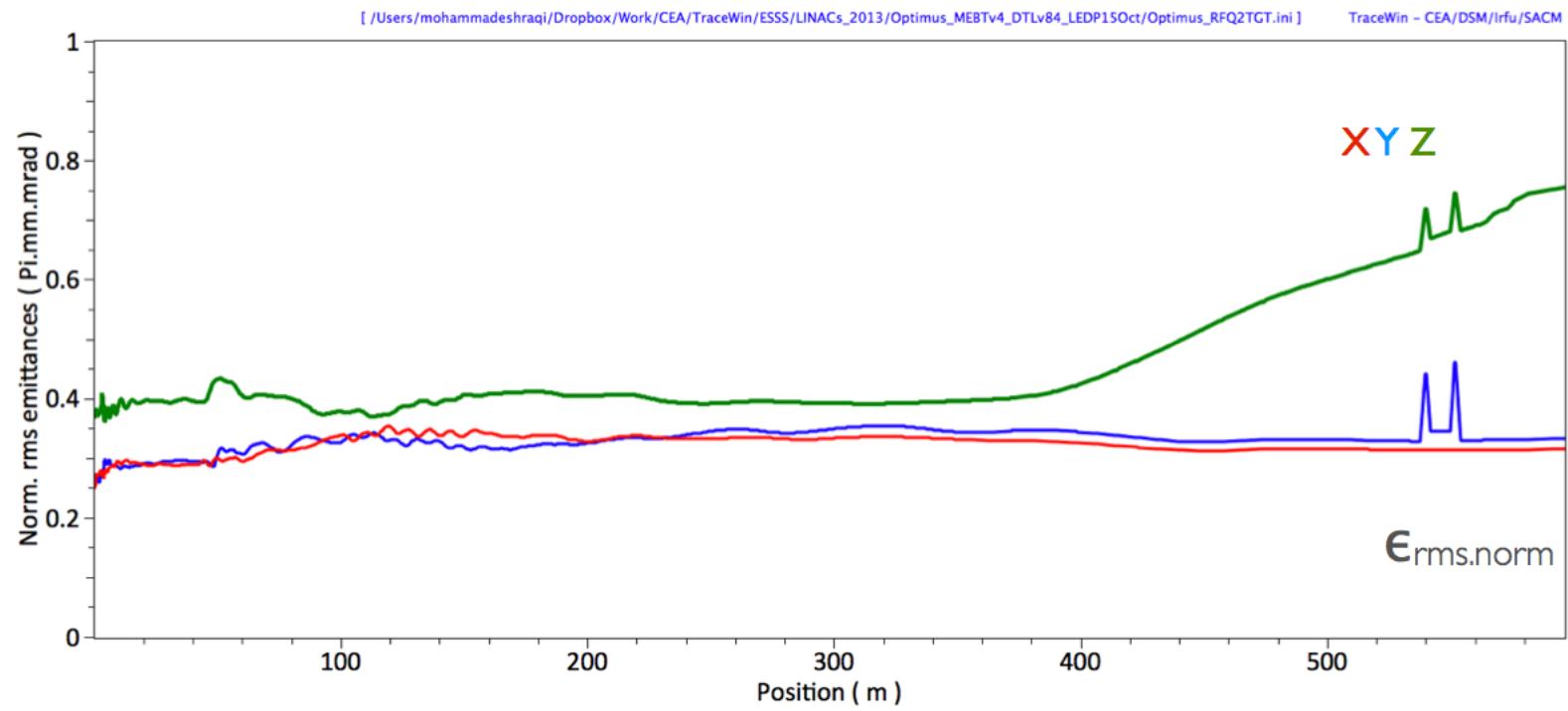
Envelopes along the linac



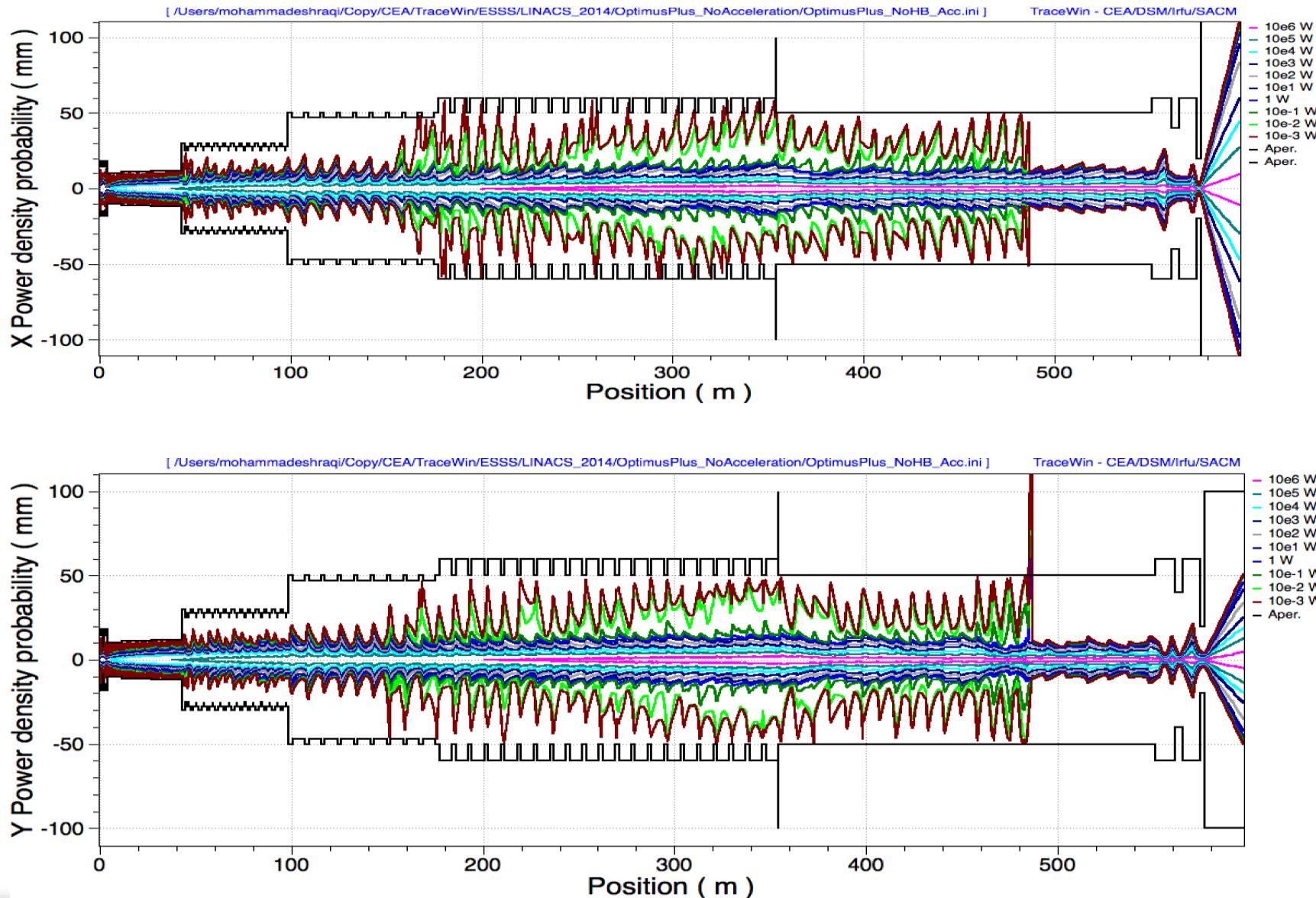
Beam size in the SCL



Emittances



Power Density



COLLABORATION DURING PRE-CONSTRUCTION



Søren Pape Møller



Roger Barlow

Pierre
Bosland



Sébastien
Bousson



Ibon Bustinduy

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UPPSALA
UNIVERSITET



Roger Ruber



LUND'S
UNIVERSITY



Anders J.
Johansson



ISTITUTO
NAZIONALE
DI FISICA
NUCLEARE



Santo Gamo



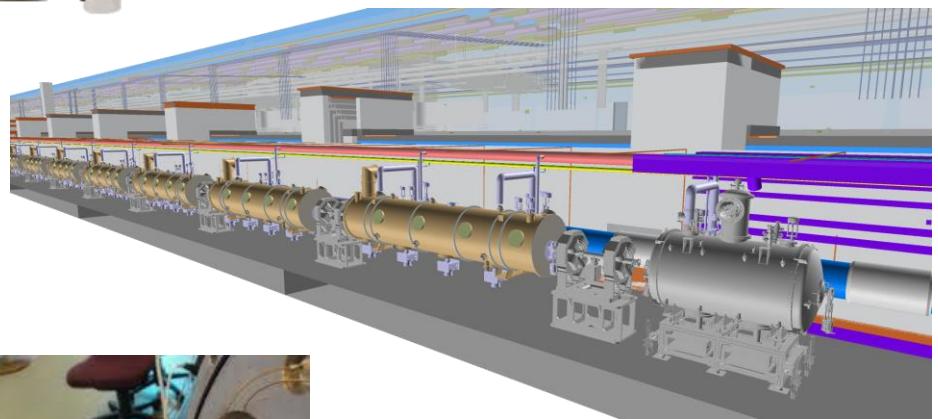
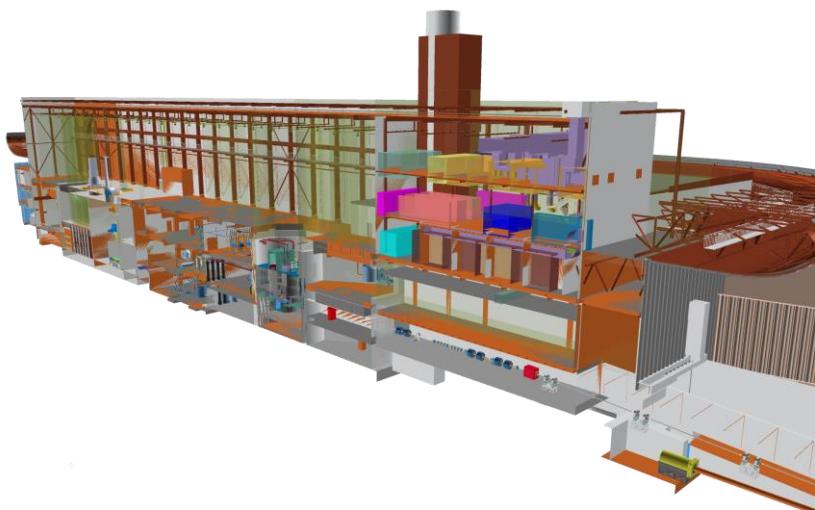
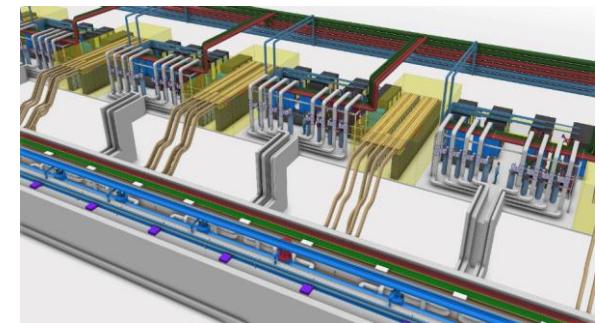
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ACCSYS Management team at ESS

- Mats Lindroos
 - Project leader
- John Weisend
 - Deputy project leader
- David McGinnis
 - Chief engineer
- Lali Tchelidze
 - Radiation Safety
- Luisella Lari
 - Head planner
- Håkand Danared
 - In-kind manager
- Anders Sunesson
 - RF systems
- Andreas Jansson
 - Beam instrumentation and general safety

- Division and project aligned at high level
 - ✓ “WP as a group” would make for too big fragmentation
 - ✓ Four WPs have external leaders
- Weekly or bi-weekly meetings at ESS Accelerator Division
 - ✓ Management board of project and division
 - ✓ WP leaders
 - ✓ Lead engineers
 - ✓ Safety
- Regular meetings for ACCSYS project
 - ✓ **Technical board** (all WP leaders and reps of labs/uni. with contract) as governance and CCB on project level (6 meetings per year)
 - ✓ Collaboration board with reps of director of of labs/uni. with contracts as oversight committee
 - ✓ Audits yearly of every WP
 - ✓ Reviews (Conceptual, design, ready to build) as required mostly co-organized with audits

And not to forget...

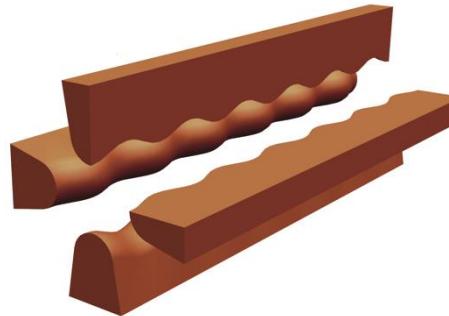


Many opportunities for
new IK partners!

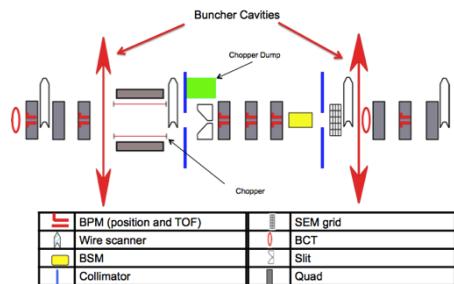
Ion Source and Normal-Conducting Linac



Prototype proton source operational, and under further development, in Catania. Output energy 75 keV.



Design exists for ESS RFQ similar to 5 m long IPHI RFQ at Saclay. Energy 75 keV->3.6 MeV.



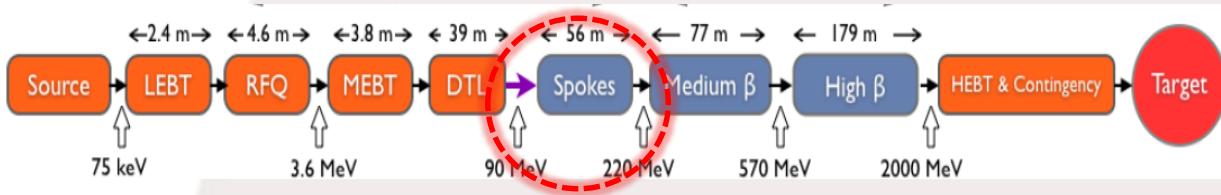
Design work at ESS Bilbao for MEBT with instrumentation, chopping and collimation.



DTL design work at ESS and in Legnaro, 3.6 ->90 MeV.

Picture from CERN Linac4 DTL.

Design of a double-spoke cavities at 352 MHz with $\beta=0.50$

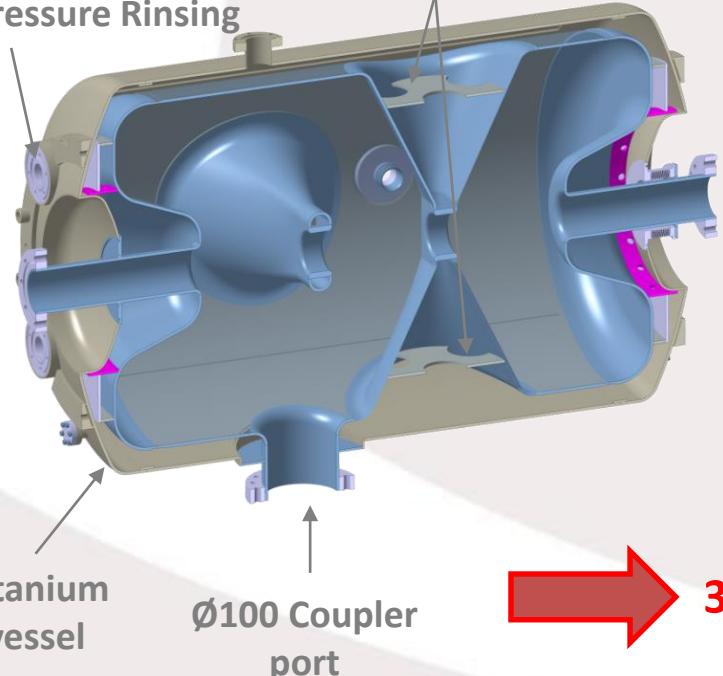


**13 cryomodules
26 spokes**

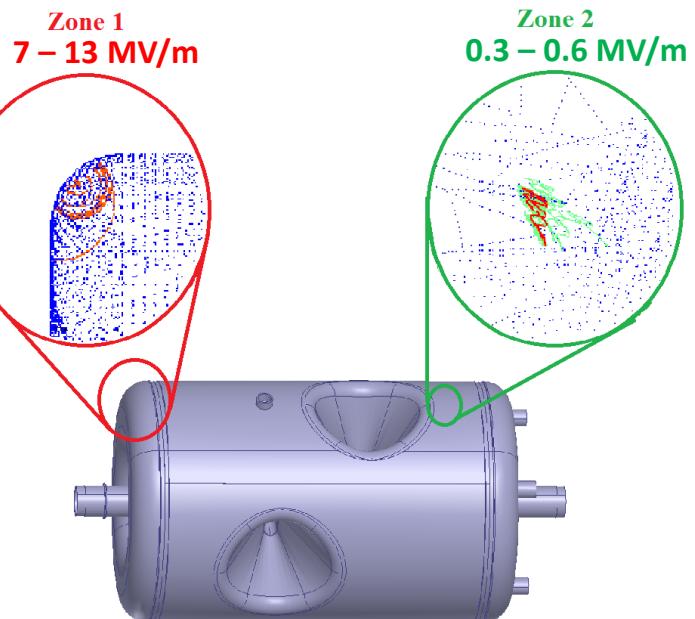
Mechanical optimisation

4 ports on cavity end-wall for High Pressure Rinsing

Stiffeners for vacuum load compensation



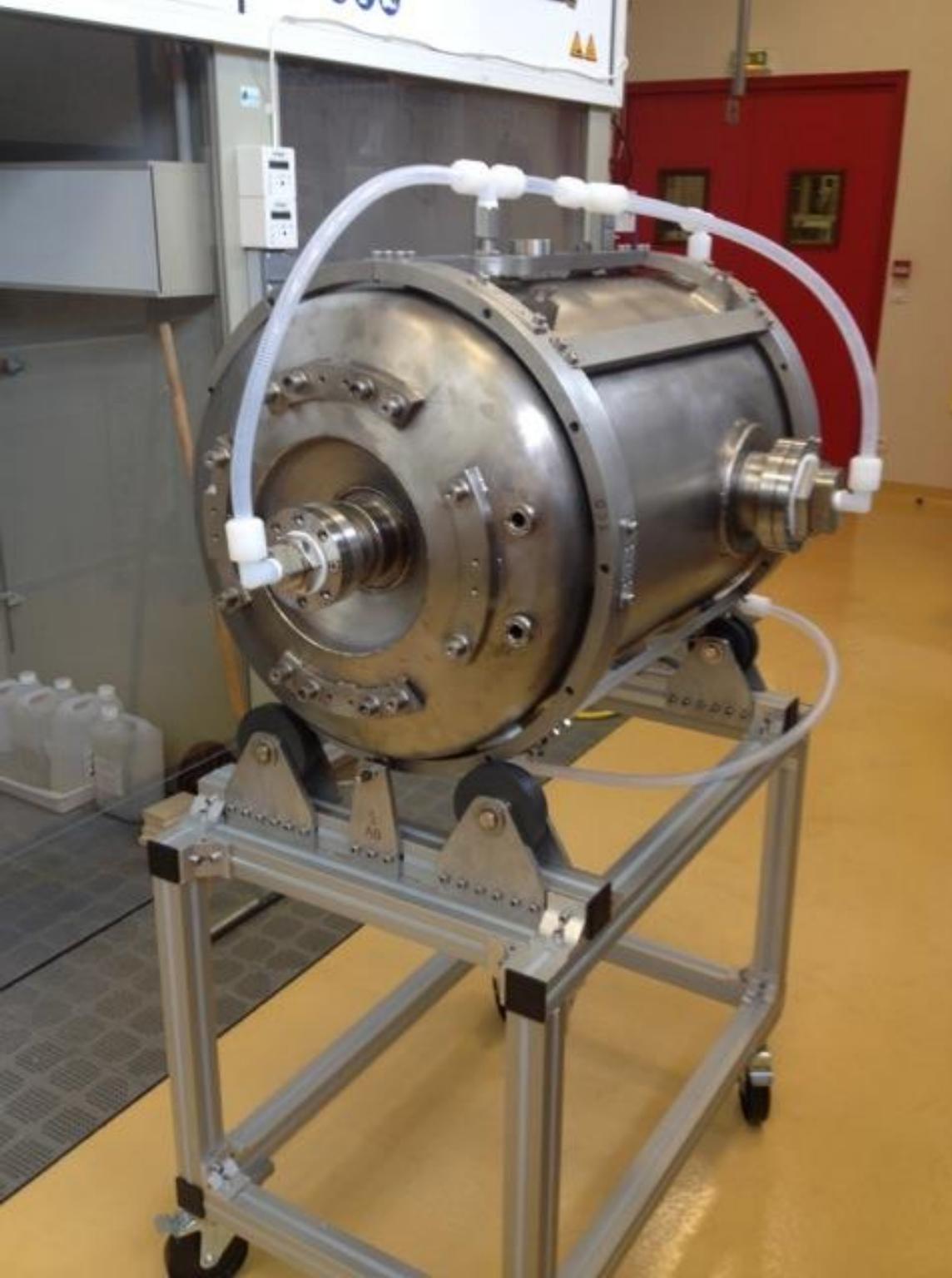
MP calculations (after final design, no optimisation)



3 Double-Spoke cavities being delivered in 2014

FIRST CAVITY RECEIVED (October 13, 2014)

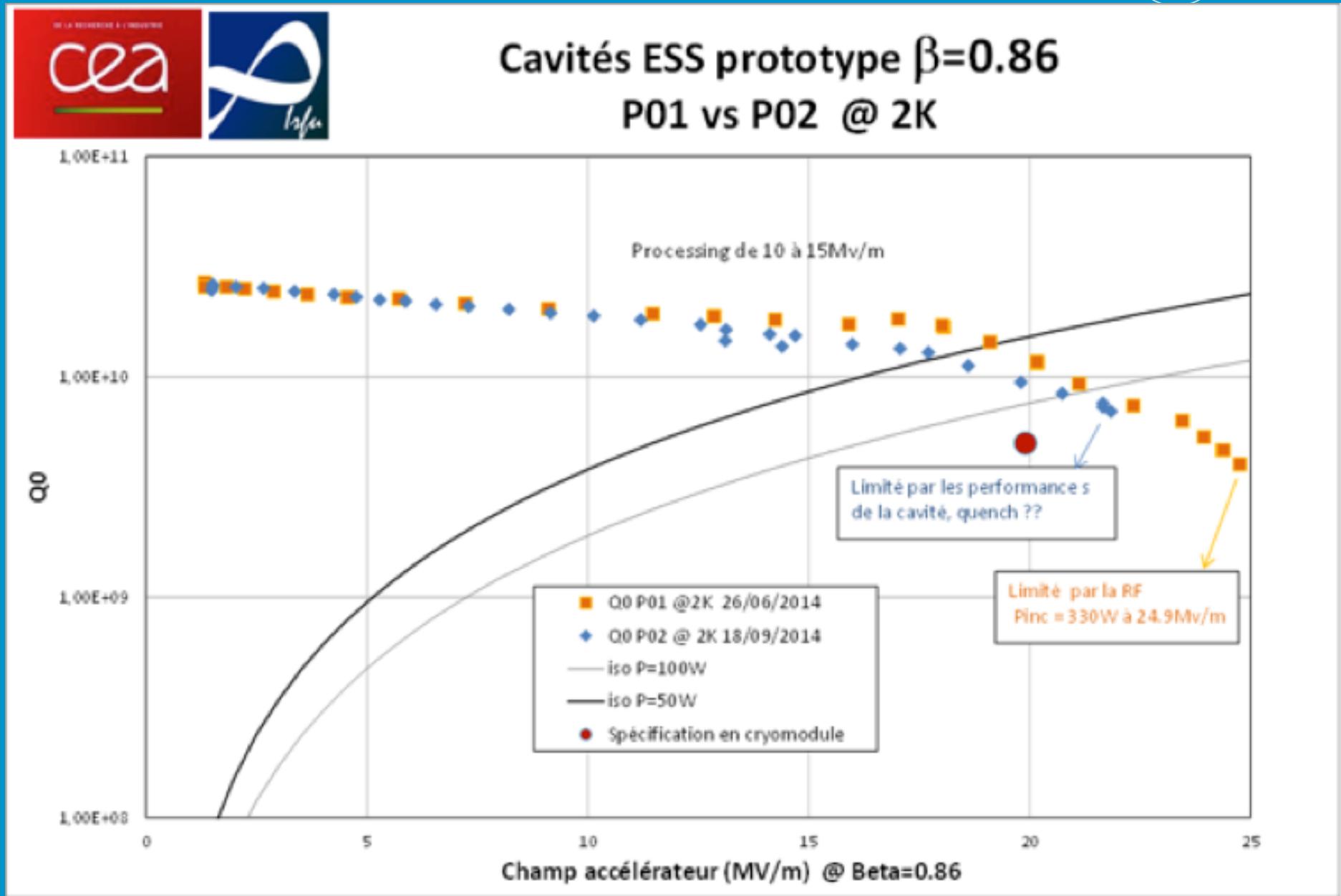




Test results of the two SRF high-beta cavities



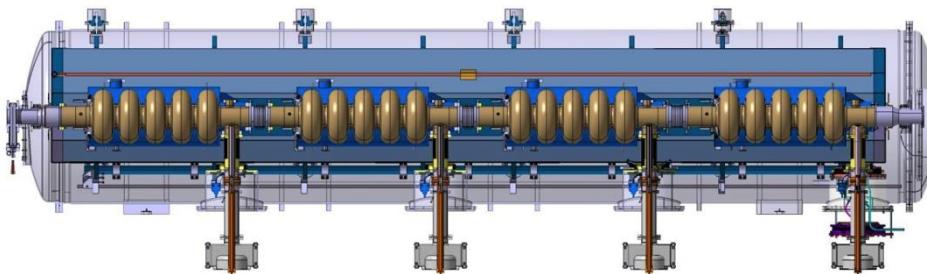
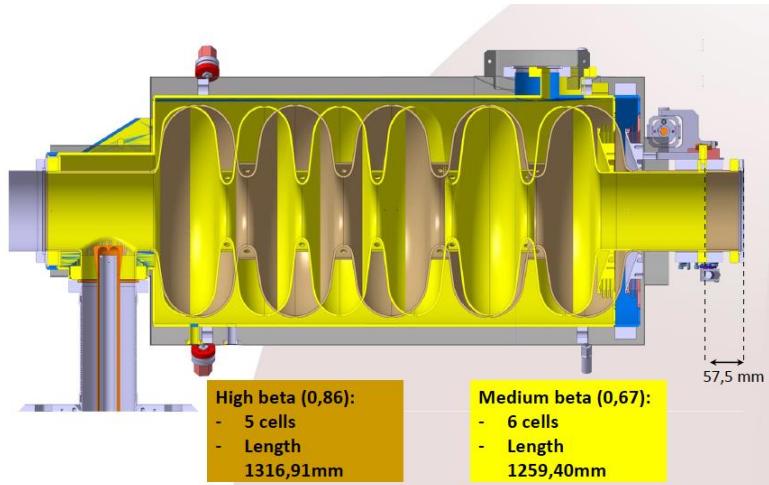
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Elliptical Cavities and Cryomodules



Superconducting five-cell elliptical cavity (not ESS). Two families, for beta = 0.67, energy 216->561 MeV and beta = 0.86, energy 561->2000 MeV.



ESS elliptical cryomodule (not final) with 4 5-cell cavities and 4 power couplers for up to ~1 MW peak RF power.

Cavity and cryomodule design well advanced at Saclay.

Elliptical Cavities
Cryomodule
Technology
Demonstrator, ECCTD,
to be ready 2015.

Cryogenics

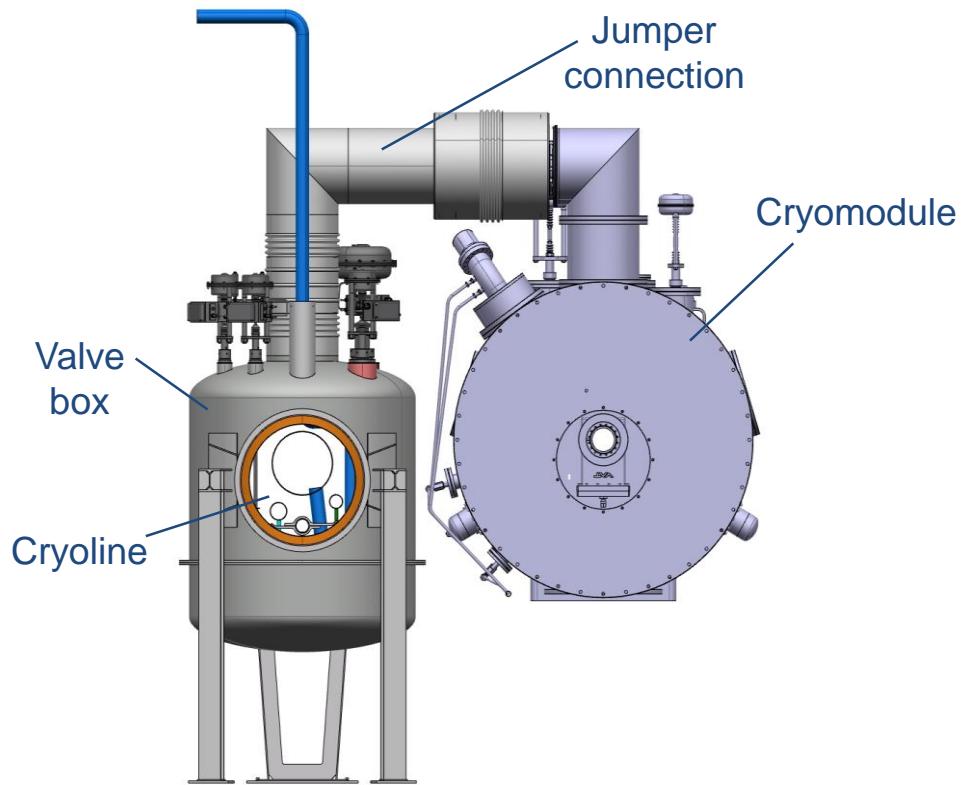
Three cryogenic plants

- Accelerator: 3.1 kW @ 2K, 12.8 kW @40 – 50 K plus 8 g/s helium liquefaction
- Target: ~ 20 kW @ 16K
- Test & Instruments ~ 250 W@ 4.5 K and 200 W @ 40K

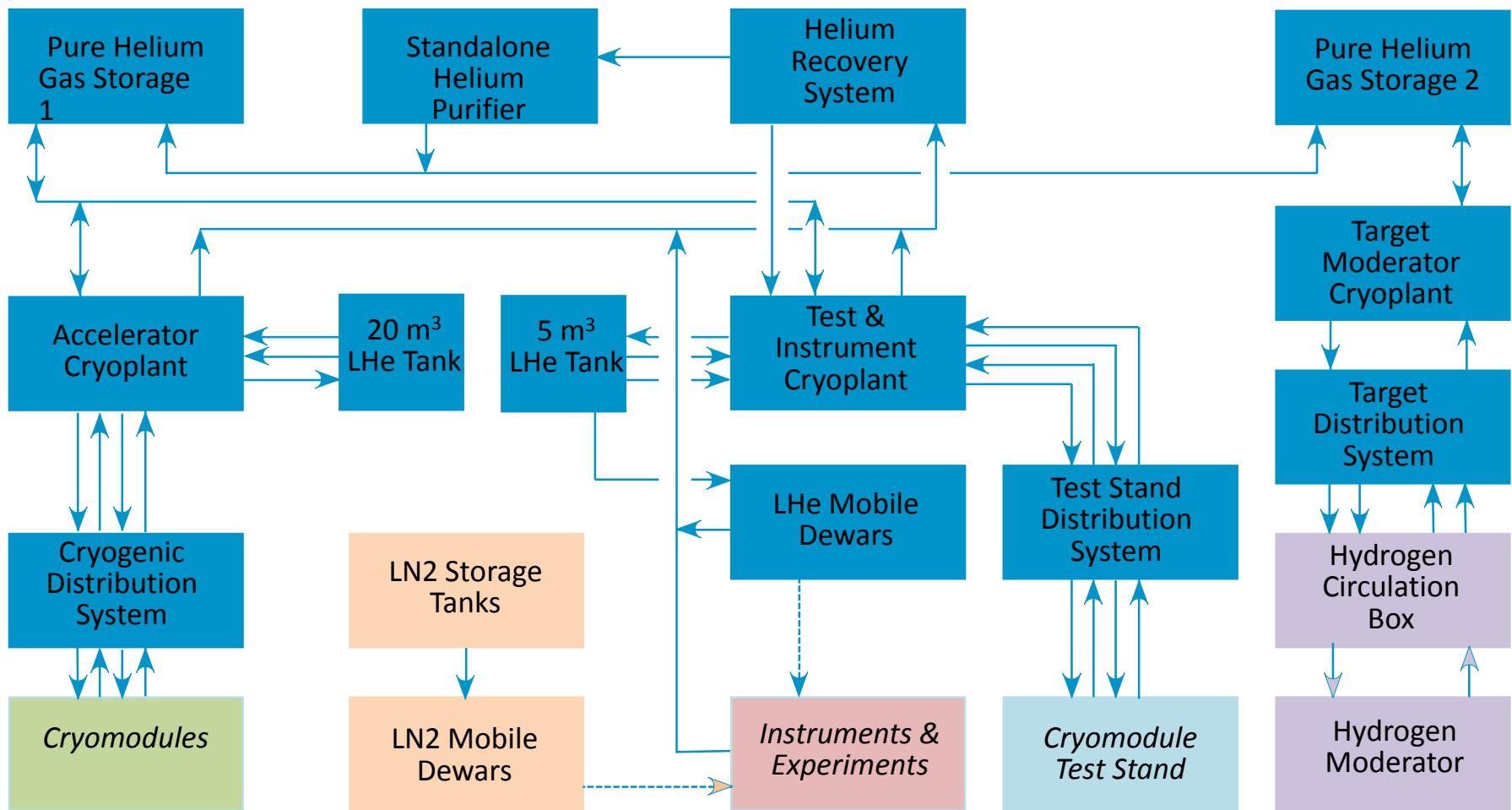
Distribution system

- Permits independent cool down & warm up of cryomodules, likely IKC

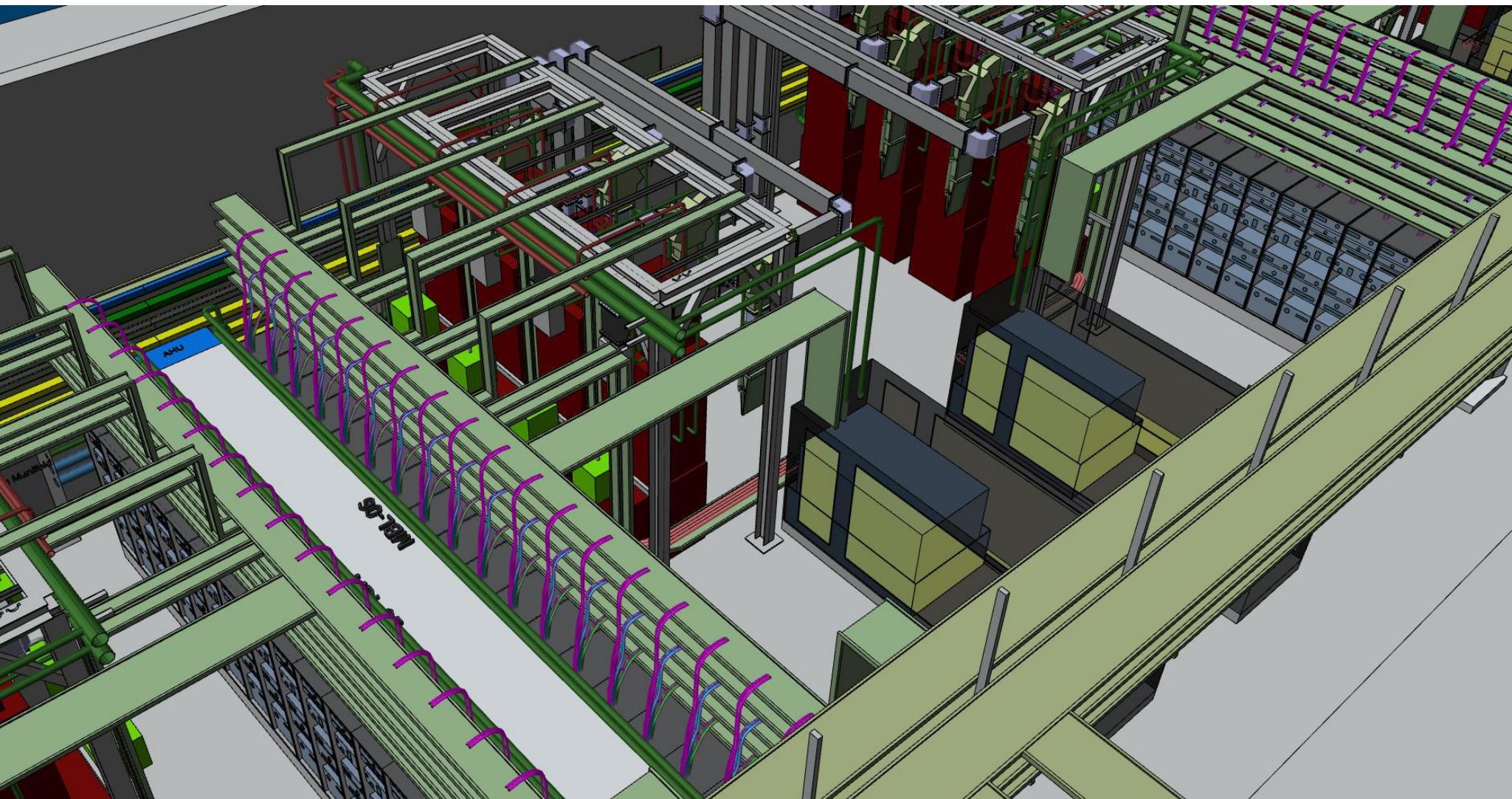
Cryoplant orders to be placed in 2015 with operations starting in 2017 – 2018



ESS Cryogenic System



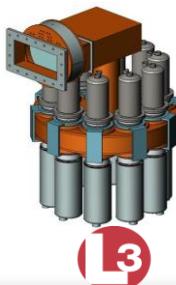
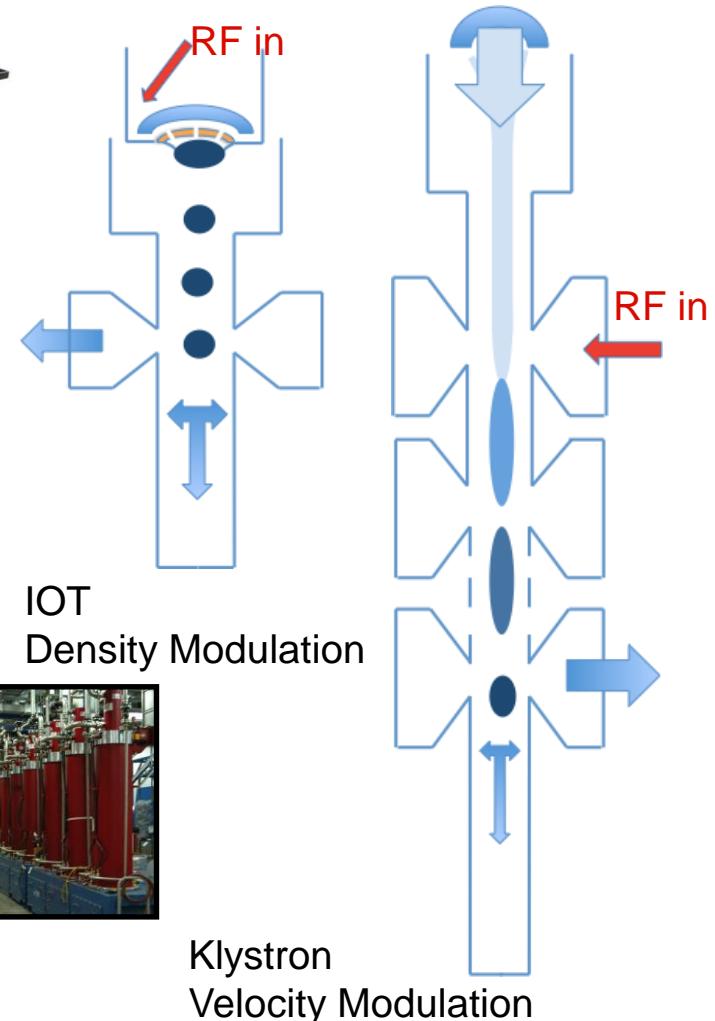
CAD view of medium/high beta RF



Inductive Output Tubes or klystrons?

- ESS

- Induction Output Tubes, IOT
 - Higher electrical efficiency
 - They don't conduct in the absence of input drive
 - Compact
 - Short MTTR
 - Cheaper modulator (No high voltage switching)
- Why suddenly IOTs?
 - Development of Pyrolytic graphite grids
 - Solid state drivers



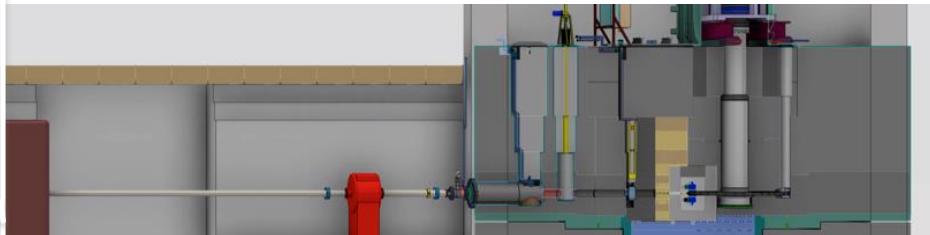
Courtesy of Morten Jensen (ESS)

Beam delivery system

Accelerator region



Target region

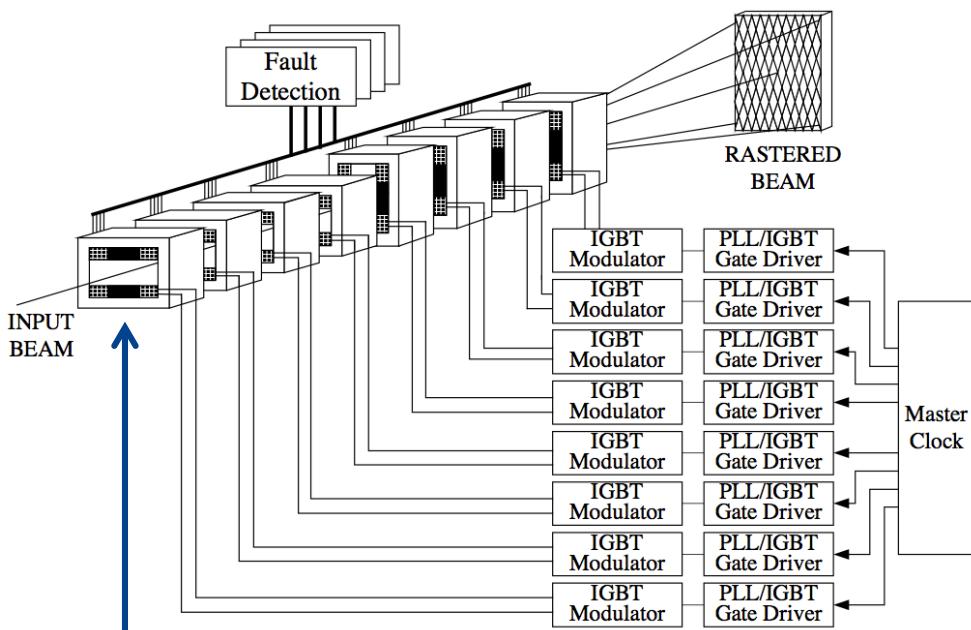


- › Small, bright beam in large aperture
- › 1 W/m onto components
- › Hands-on maintenance

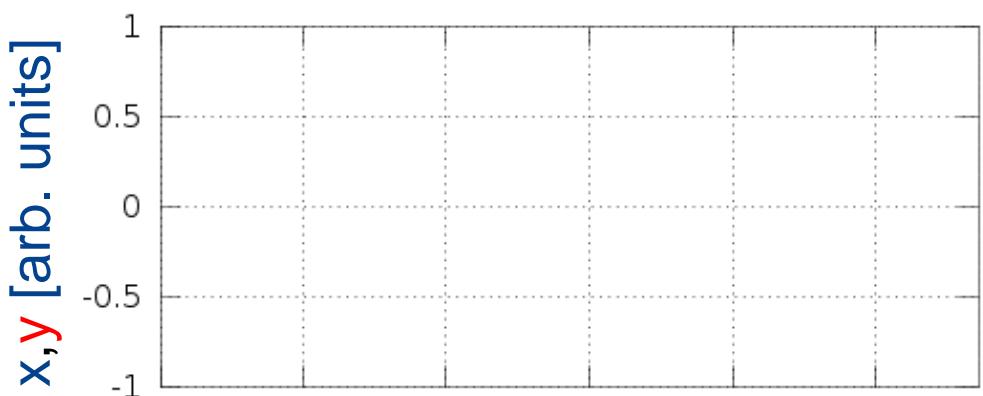
- Large beam to compact target/moderator
- 5 MW onto components
- Remote maintenance

LANL APT: Final Design

20 ms pattern cycle



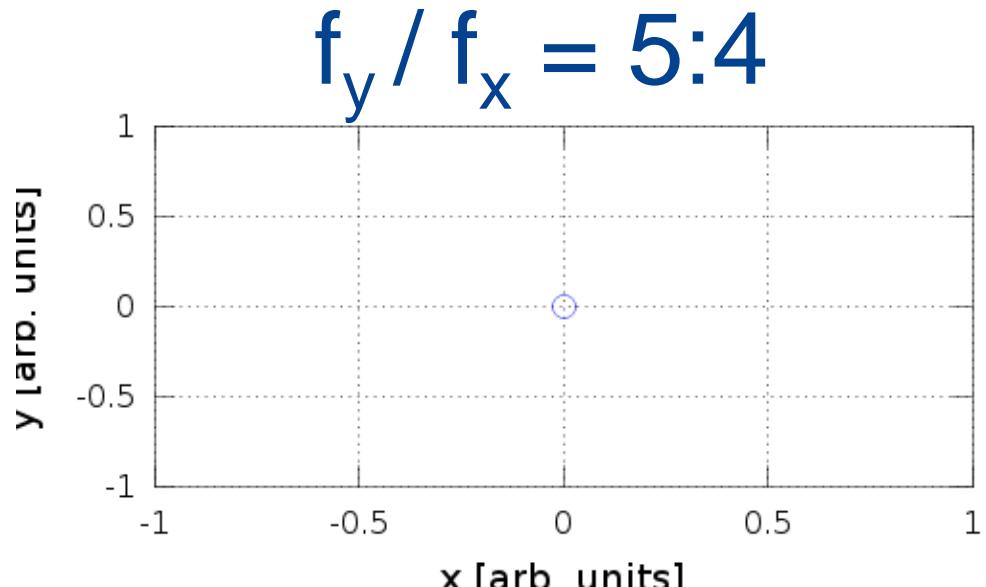
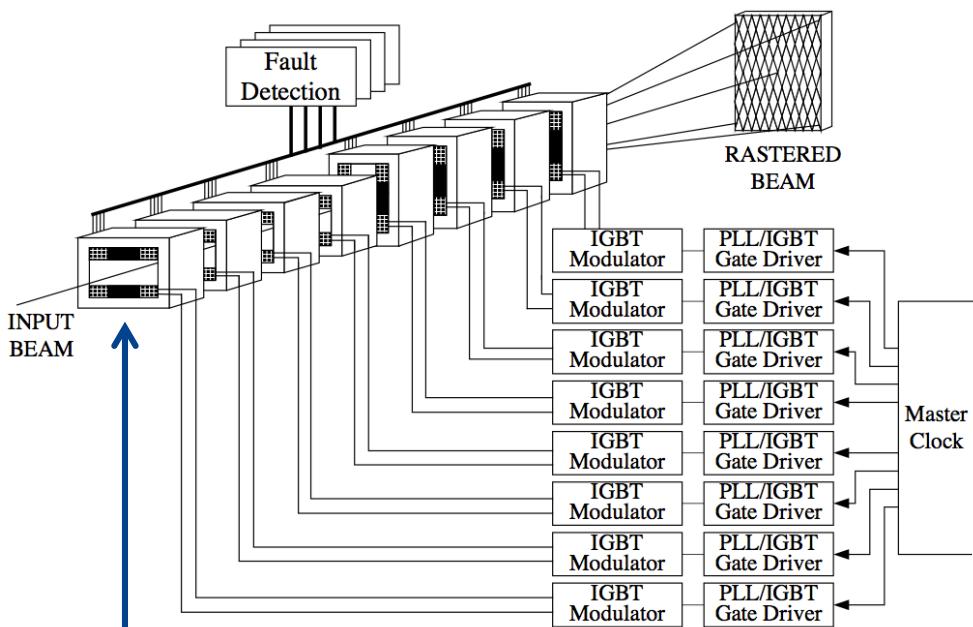
$$f_y / f_x = 5:4$$



One pattern cycle

LANL APT: Final Design

20 ms pattern cycle



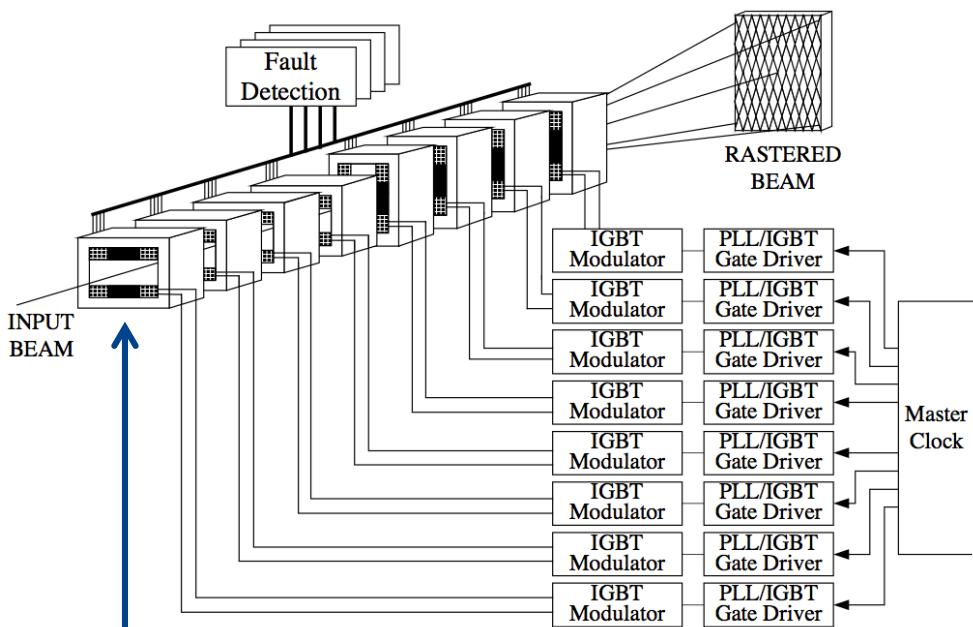
ESS Challenges:

$> f \sim 40 \text{ kHz}, T_{\text{p-p}} = 12.5 \text{ us}$

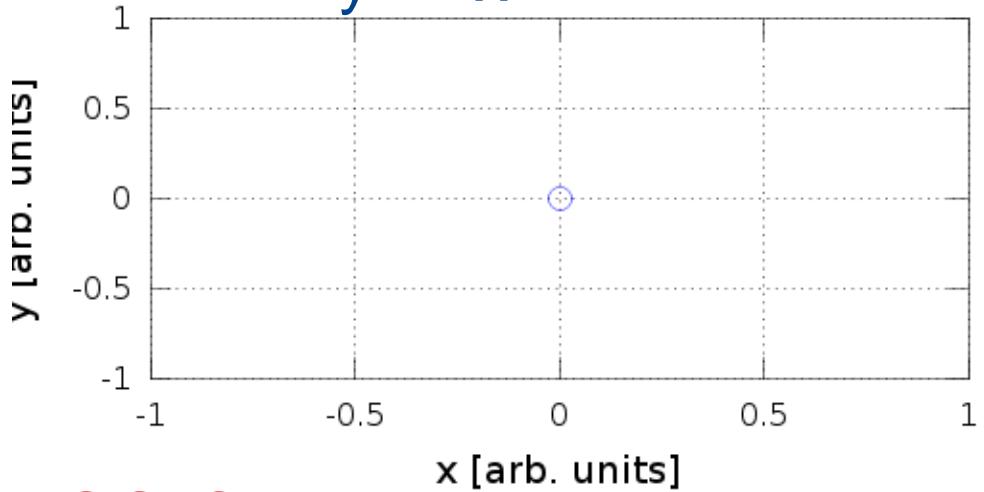


LANL APT: Final Design

20 ms pattern cycle



$$f_y / f_x = 5:4$$

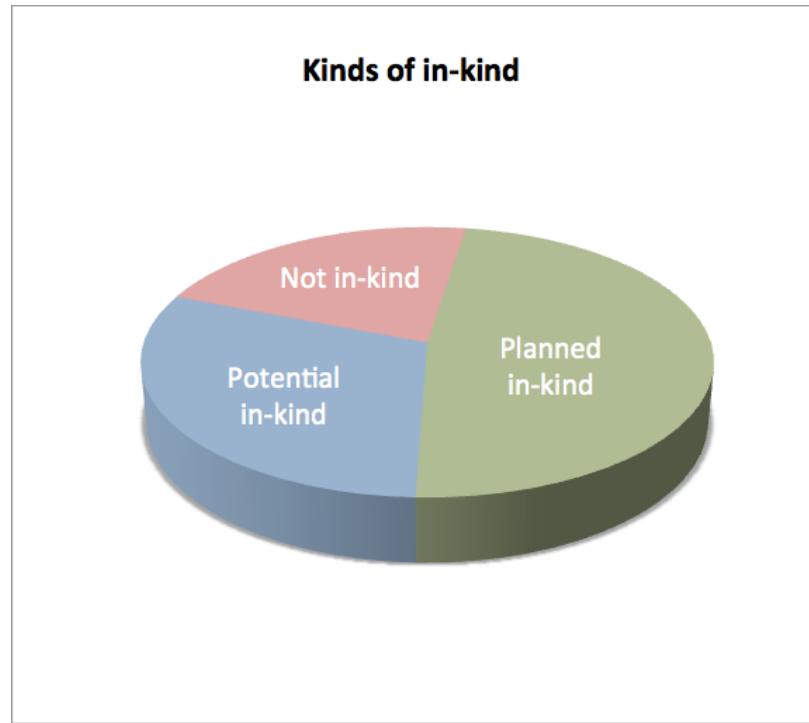


ESS Challenges:

$> f \sim 40 \text{ kHz}, T_{\text{p-p}} = 12.5 \text{ us}$

$\text{Max}(\Delta x) = 70 \text{ mm}, \text{max}(\Delta y) = 16 \text{ mm},$
 $\text{RMS}(x-\Delta x) = 12.6 \text{ mm}, \text{RMS}(y-\Delta y) = 6.3 \text{ mm}$

ACCSYS update in-kind discussions



- Potential partners identified for 47% of the total planned/potential in-kind value
- Planned/potential in-kind is 78% of accelerator budget
- Many activities start 2014, reflecting the importance of reaching agreements soon

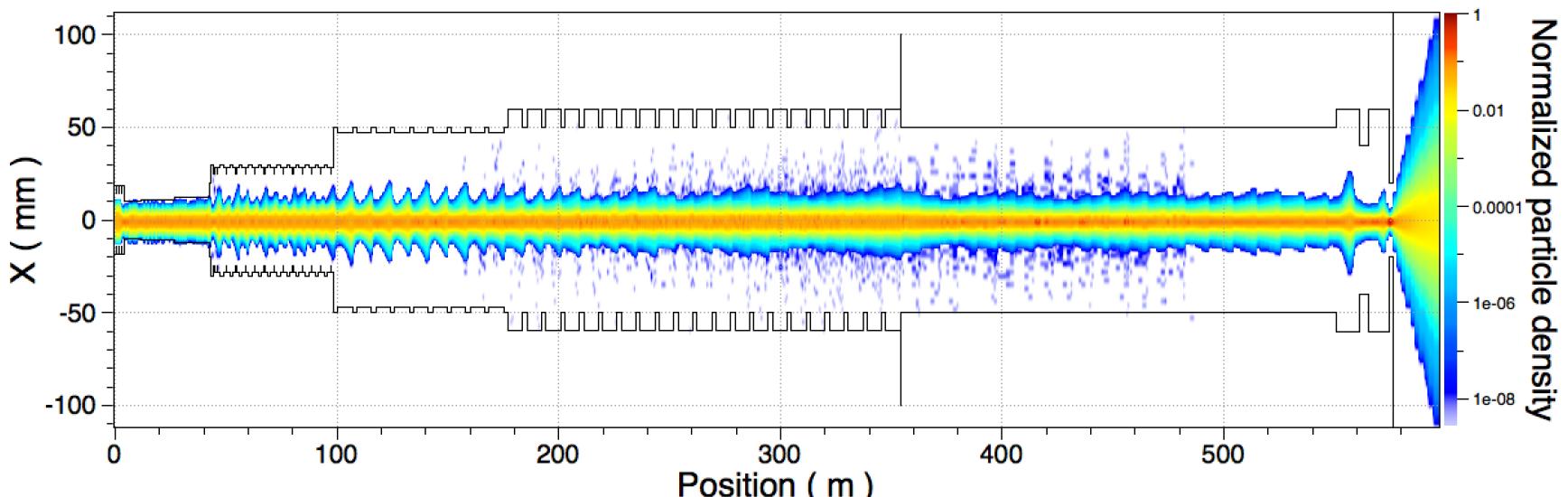
Collaborations enable discovery!

- **The ESS design update:**
 - A highly collaborative project
 - A baseline design based on the most suitable and best technology of today
 - Enough time for ESS to recruit skilled staff further design work and for coordination and integration
- **Collaborations enabled the design update process to complete in time for the construction phase**
 - Partners from Pre-Construction have expressed their intention to continue through Construction. Contracts under signature.
 - Discussions under way with additional partners for the construction stage, many new opportunities identified! Contracts under being prepared!
 - Crucial to keep the schedule
- **Thanks for good support – join us on a wonderful journey ahead!**

Density

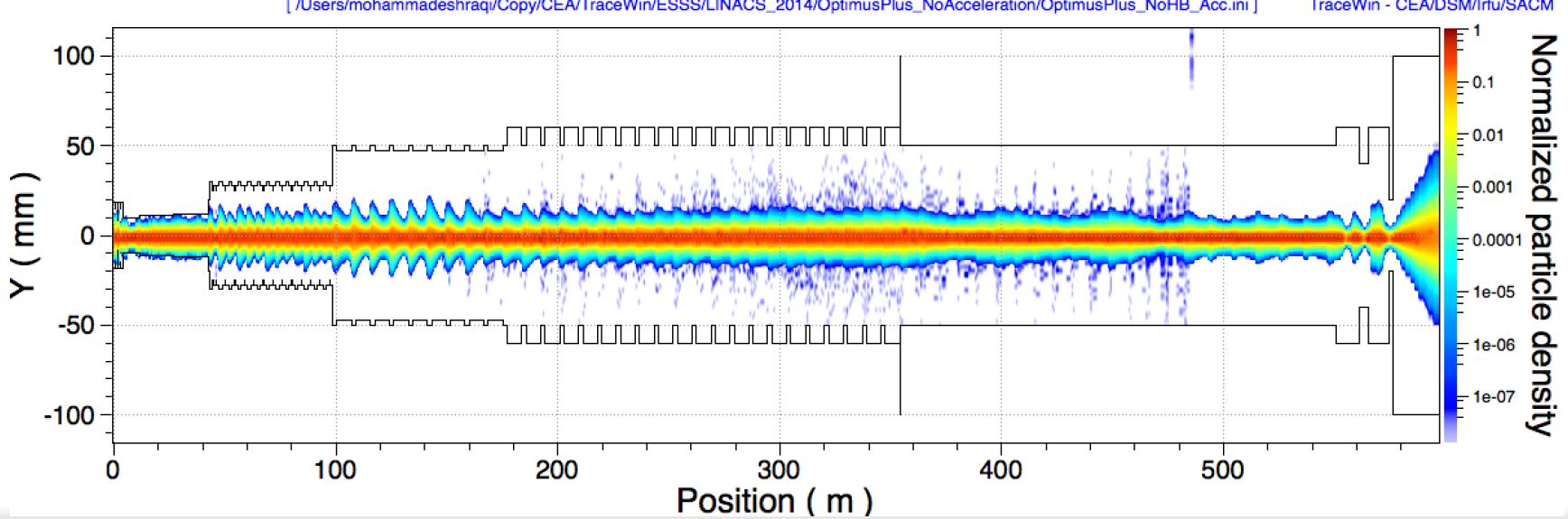
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TraceWin - CEA/DSM/lrfu/SACM

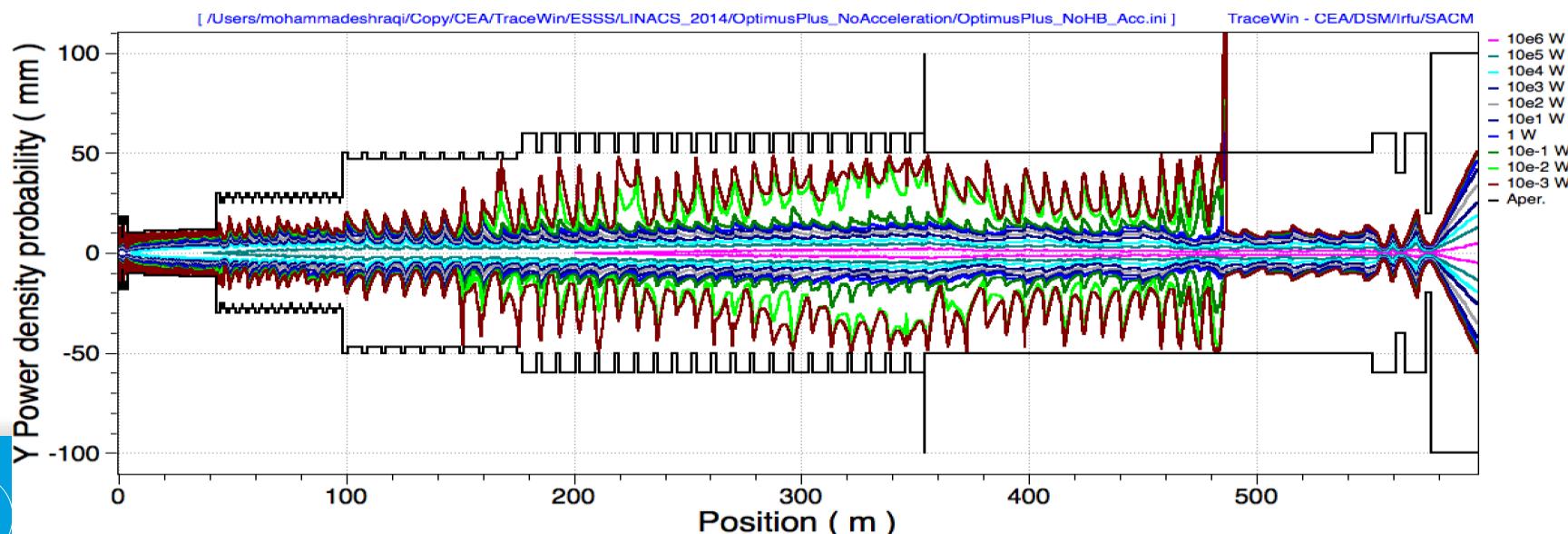
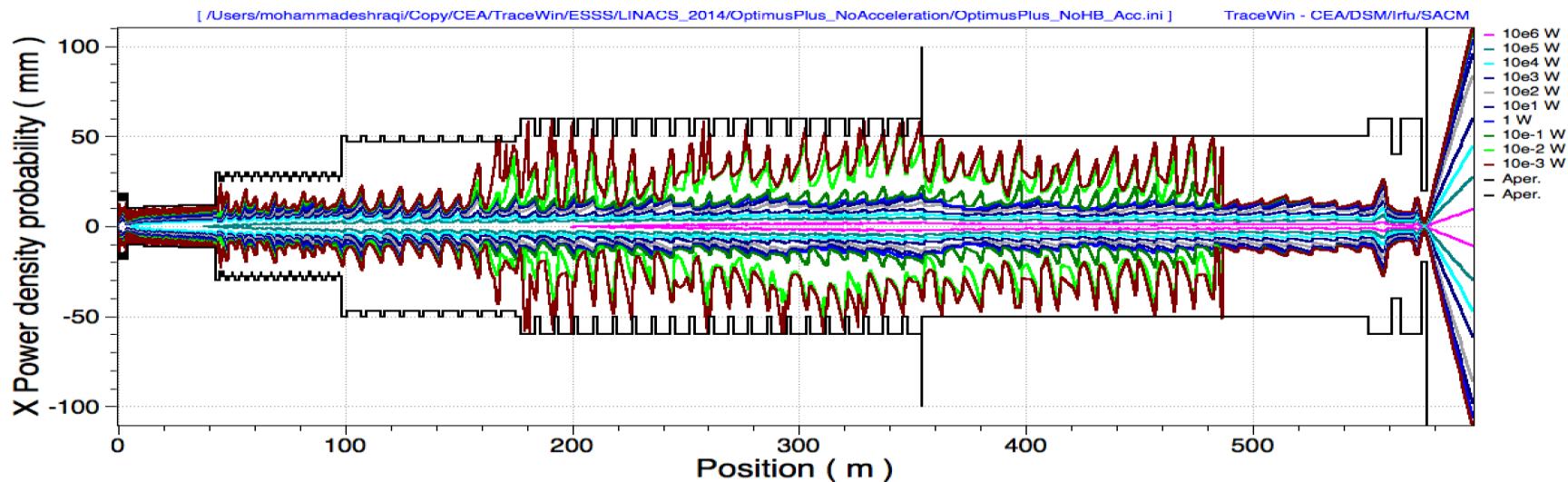


[/Users/mohammadesraqi/Copy/CEA/TraceWin/ESSS/LINACS_2014/OptimusPlus_NoAcceleration/OptimusPlus_NoHB_Acc.ini]

TraceWin - CEA/DSM/lrfu/SACM



Power Density

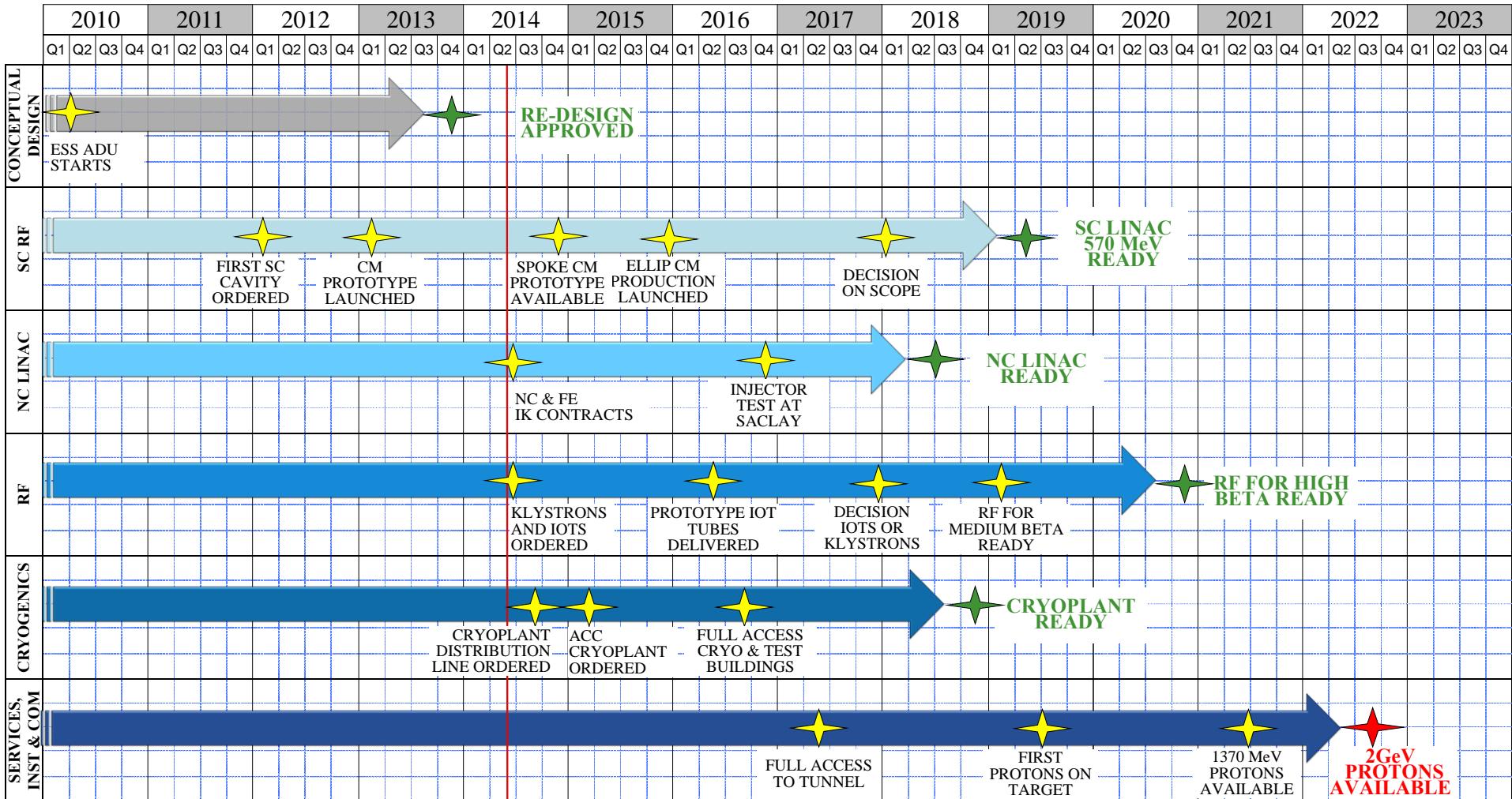


Plans



EUROPEAN
SPALLATION
SOURCE

HIGH LEVEL SCHEDULE - ESS ACCELERATOR



EUROPEAN
SPALLATION
SOURCE



Aug '14

Design and specifications:

-ESS and LTH;

R&D and training of Highly Qualified Personnel:

-LTH (3 MSc thesis, 5 Research associate, 1 PhD thesis starting Jan 2015);

Control system hardware :

-National Instruments AB, Skåne business center;

Control system software :

-Lund University Innovation System (LUIS) AB;

Construction (Low Voltage part):

- AQ Elautomatik AB, in Lund;



**LUND
UNIVERSITY**



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SYSTEM**



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