The European Spallation Source

Steve Peggs,
for ESS/AD & the ADU collaboration

23 ESS papers at IPAC11

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MOODB02	**Stephen Molloy**	RF Modeling Plans for the ESS
MOPC049	**Robert Ainsworth**	Bead-pull Test Bench for Studying Accelerating Structures at RHUL
MOPC050	**Stephen Molloy**	Multipacting Analysis for the SRF Cavity HOM Couplers in ESS
MOPC136	**Karin Rathsman**	The RF Power Source for the High Beta Elliptical Cavities of the ESS
MOPC161	**Anders J Johansson**	Challenges for the Low Level RF Design for ESS
MOPS039	**Aurélien Ponton**	High Power Proton Linac Front-End: Beam Dynamics ... for the ESS
MOPS082	**Carsten Welsch**	... Choice of Frequency & Geometrical Beta in ... Proton Linacs …
TUPC131	**Lali Tchelidze**	Overview of ESS Beam Loss Monitoring System
TUPS096	**Karin Rathsman**	ESS Parameter List Database and Web Interface Tools
TUZB01	**Guillaume Devanz**	Superconducting RF Technology for Proton and Ion Accelerators
WEIB05	**Cristina Oyon**	Collaborative R&D in the Industry of Science
WEPC166	**Thomas Hansson**	Licensing and Safety Issues of the ESS Accelerator
WEPS059	**Håkan Danared**	Layout of the ESS Proton Linac
WEPS060	**Mohammad Eshraqi**	Design and Optimization of the ESS LINAC
WEPS061	**Mohammad Eshraqi**	ESS LINAC, Design and Beam Dynamics
WEPS062	**Mohammad Eshraqi**	Design and Beam Dynamics Study of Hybrid ESS LINAC
WEPS063	**Mohammad Eshraqi**	Compensation of ... Malfunctioning Spoke Resonators [in] ESS
WEPS064	**Mats Lindroos**	Upgrade Strategies for High Power Proton Linacs
THEA01	**Colin Carlile**	Is it Possible to Operate a Large Research Facility with Wind Power?
THPS031	**Heine Thomsen**	The Beam Expander System for the ESS
THPS050	**Anne Holm**	The High Energy Beam Transport System for the ESS
THXA01	**Igor Verstovsek**	Recent Trends in Accelerator Control Systems

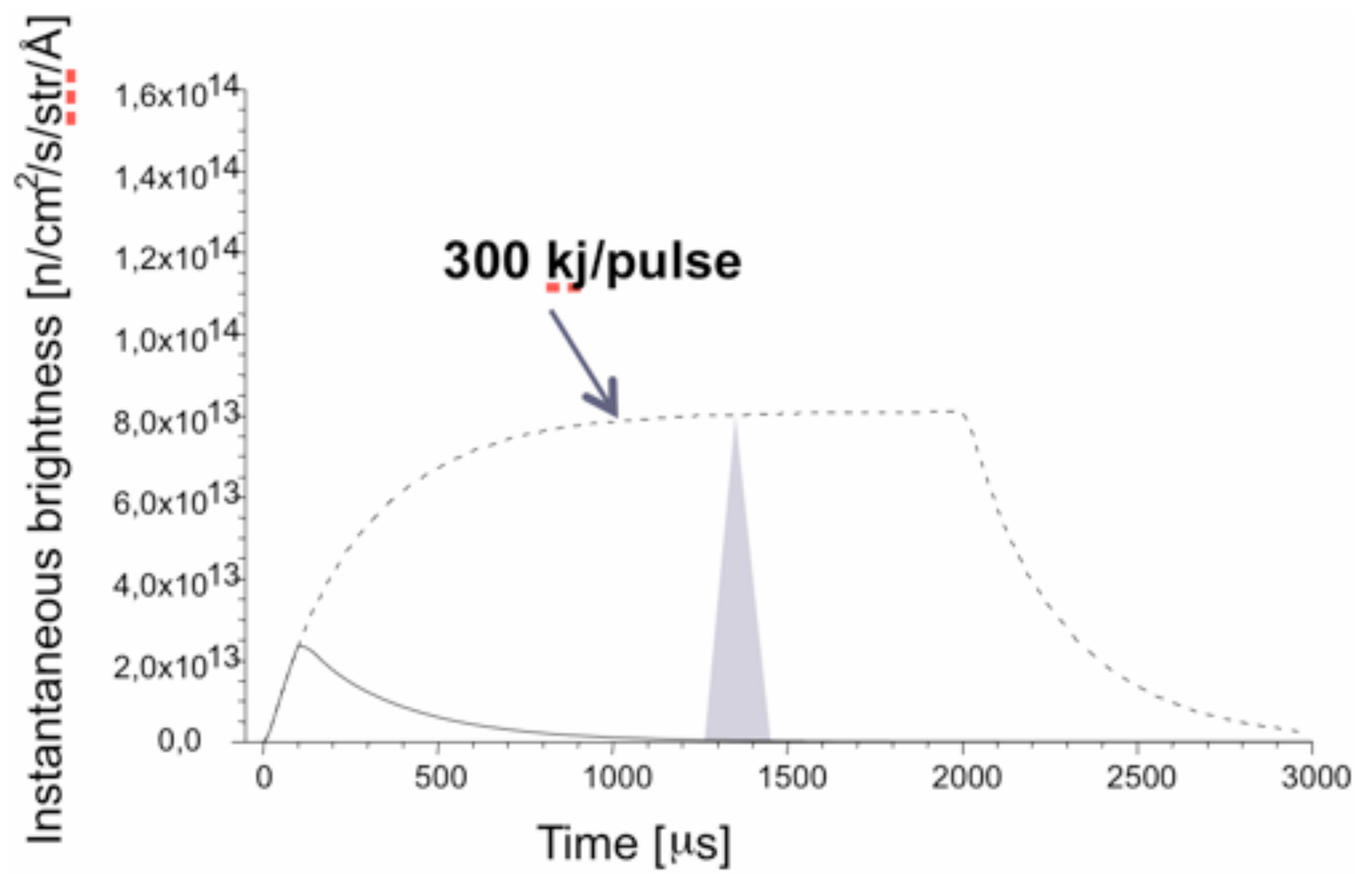
Q: Why ESS?
A: **Long** pulses of cold neutrons

Many research reactors in Europe are aging & will close before 2020
- Up to 90% of their use is with cold neutrons

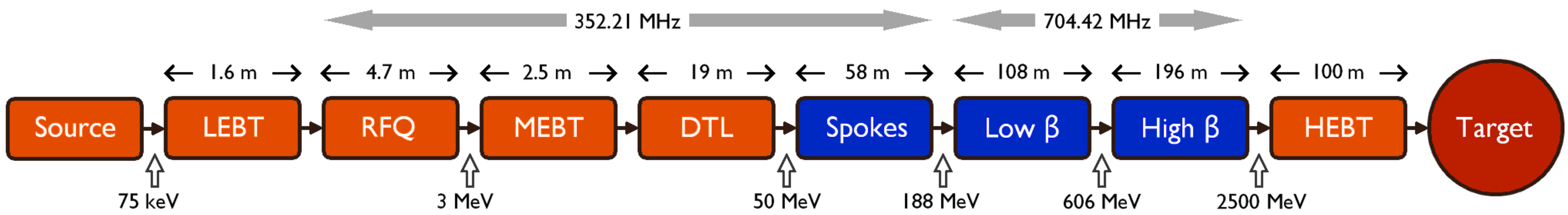
There is a urgent need for a new **high flux cold neutron** source
- Most users are fully satisfied by a long pulse source
- Existing short pulse sources (ISIS, JPARC, SNS) can supply the present and imminent future need of short pulse users

"Pulsed cold neutrons will always be long pulsed as a result of the moderation process"

F. Mezei, NIM A, 2006



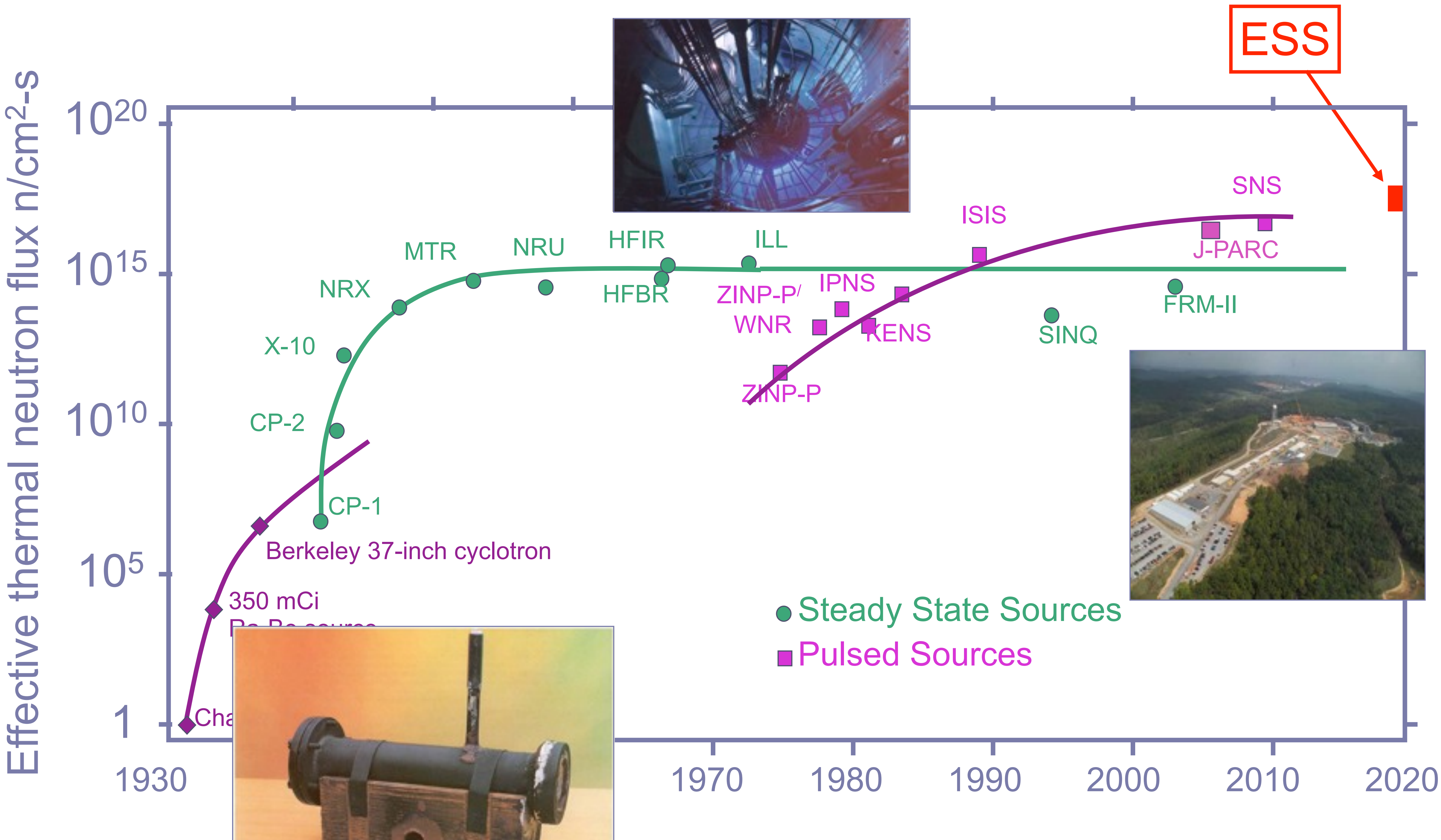
Neutrons in 2019 !



5	MW	beam power
2.5	GeV	protons (H+)
2.9	ms	pulses
14	Hz	rep rate
50	mA	pulse current
704	MHz	RF frequency
< 1	W/m	beam losses
7.5	MW	upgradability?

NO H- injection, no accumulator/compressor ring) !

Evolution of neutron sources



...eutron Scattering, K. Skold and D. L. Price, eds., Academic Press, 1986)

ESS technology on the ADS roadmap

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Finding #5: "The missions for Accelerator Driven Sub-critical (ADS) technology lend themselves to a technology development, demonstration & deployment strategy in which successively complex missions build upon technical developments of the preceding mission."
U.S. Dept. of Energy White Paper (2010).

Table 2: Accelerator Requirements for three reference ADS Designs

	Transmutation Demonstration (MYRRHA [5])		Industrial Scale Facility driving single subcritical core (EFIT [10])	Industrial Scale Facility driving multiple subcritical cores (ATW [11])
Beam Energy [GeV]	0.6	2.5	0.8	1.0
Beam Power [MW]	1.5	5.0-7.5	16	45
Beam current [mA]	2.5	[**50]	20	45
Uncontrolled Beamloss	< 1 W/m	< 1	< 1 W/m	< 1 W/m
Fractional beamloss at full energy (ppm/m)	< 0.7		< 0.06	< 0.02

ESS [**50 mA in 2.9 ms pulses at 14 Hz]

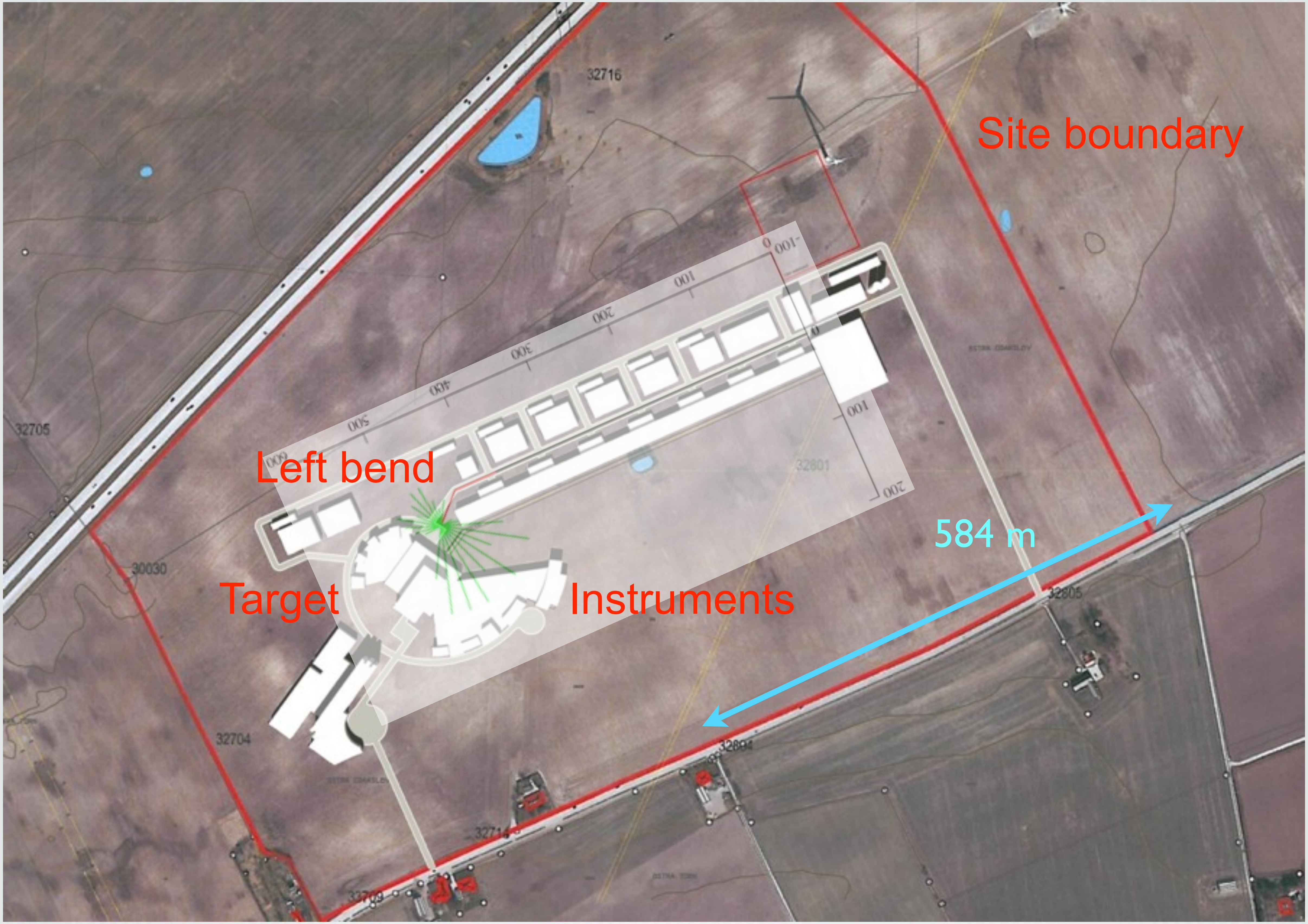
Green (field) site

The ESS site is in Sweden !

Sweden, Denmark & Norway cover 50% of cost

The other 14 member states covers the rest, with the European Investment Bank

2009 - Artists concept



2011 - Fixed linac end & target

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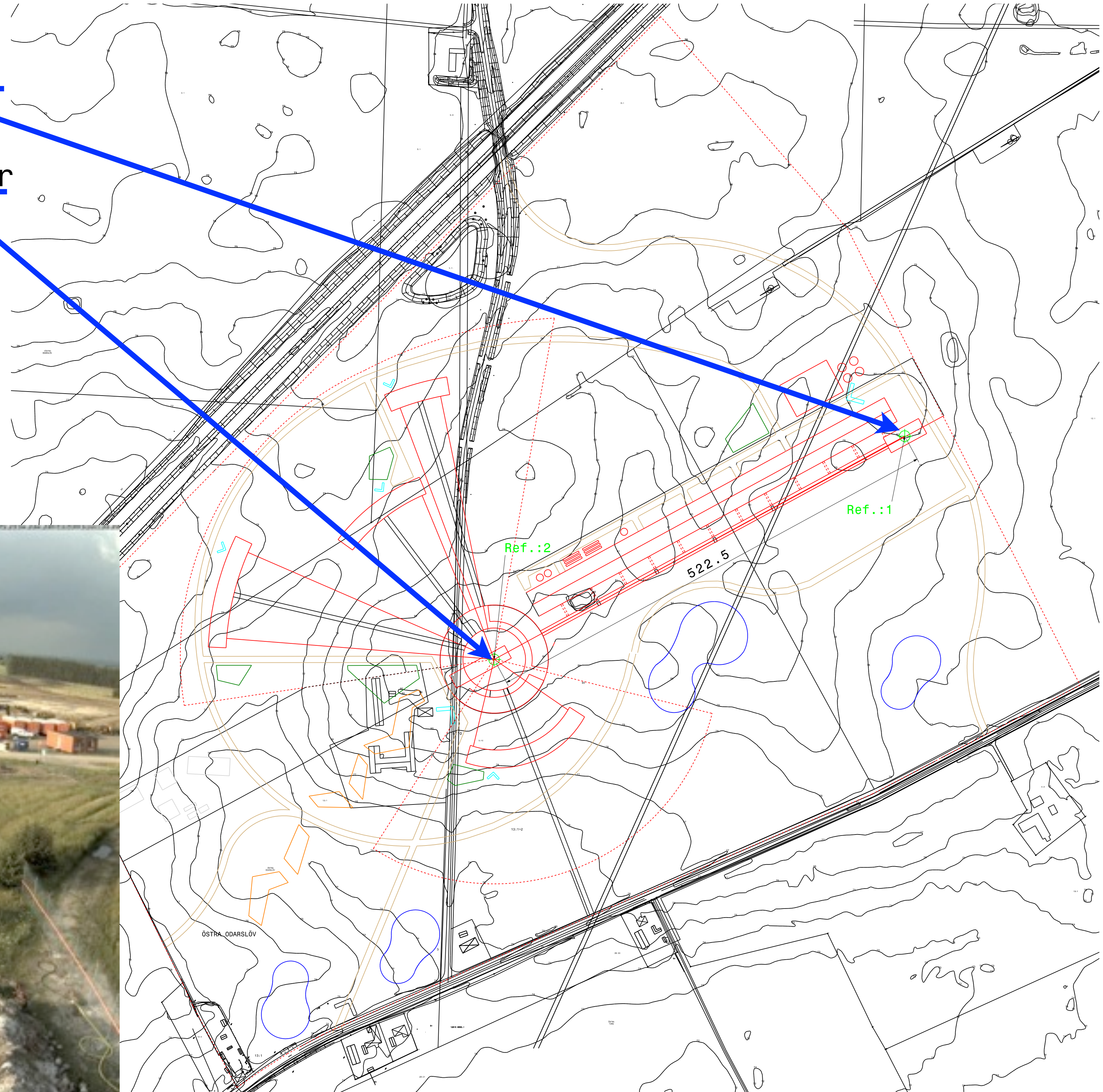
Note:
SWEREF coordinates

Ref.:1 Accelerator start
X: 134692.1
Y: 6179297.63
Ref.:2 Target station center
X: 134233.00
Y: 6179048.00



Max-IV under construction

The ESS green field

32-28 MW - the green strategy

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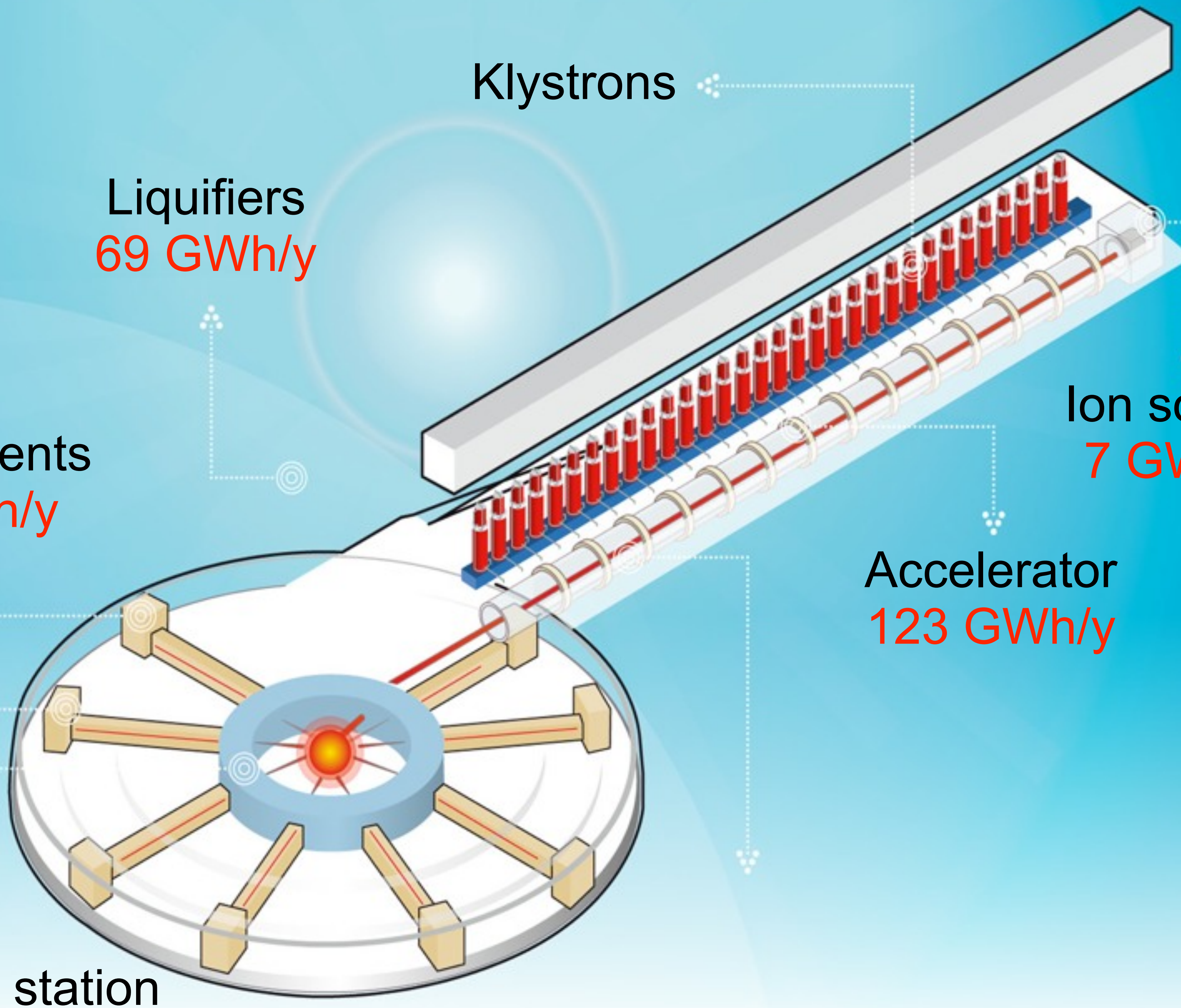
SUSTAINABILITY PARTNERS

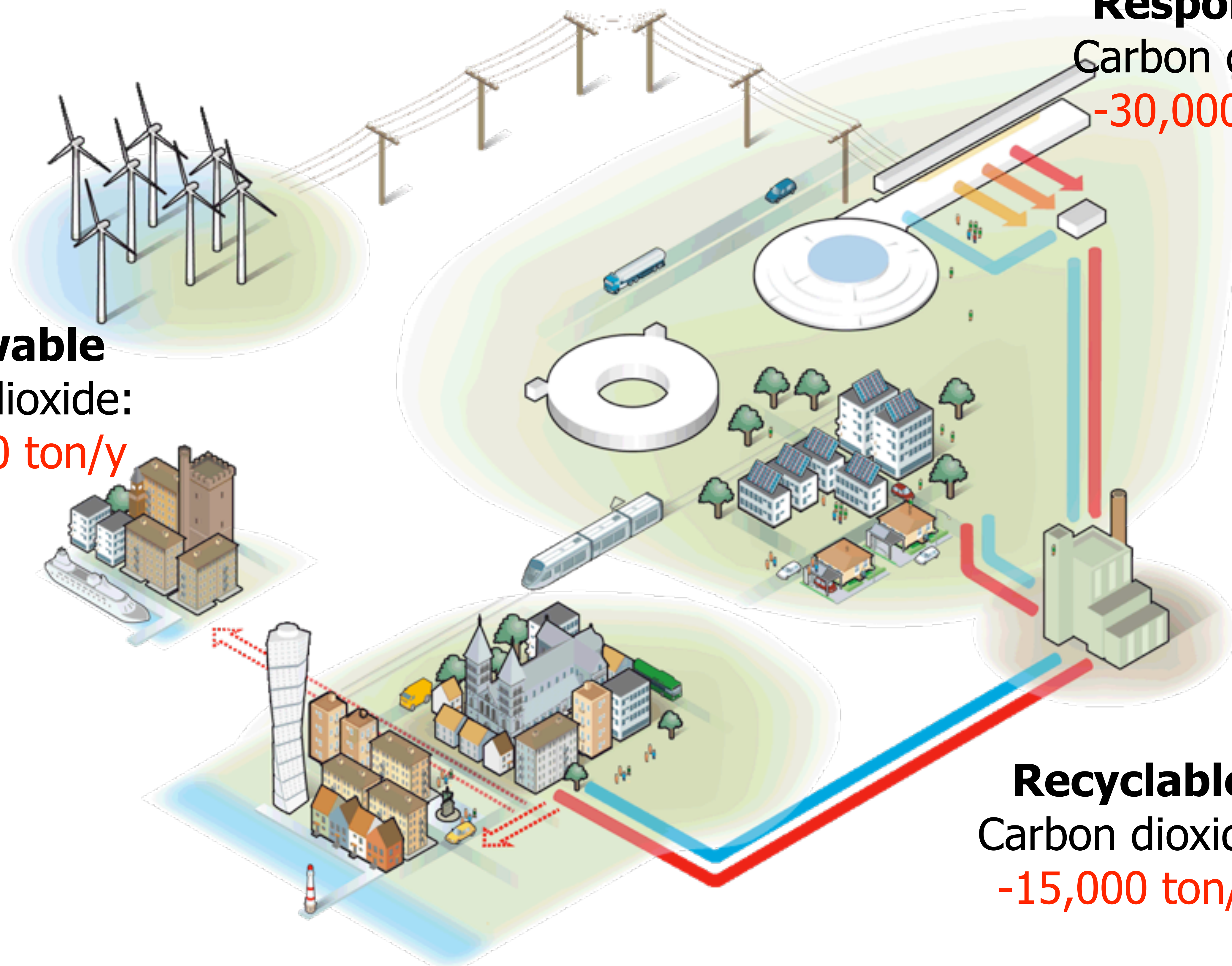
e·on LUNDS ENERGI



The sustainable way

Renewable
Carbon dioxide:
-120,000 ton/y

Responsible
Carbon dioxide:
-30,000 ton/y

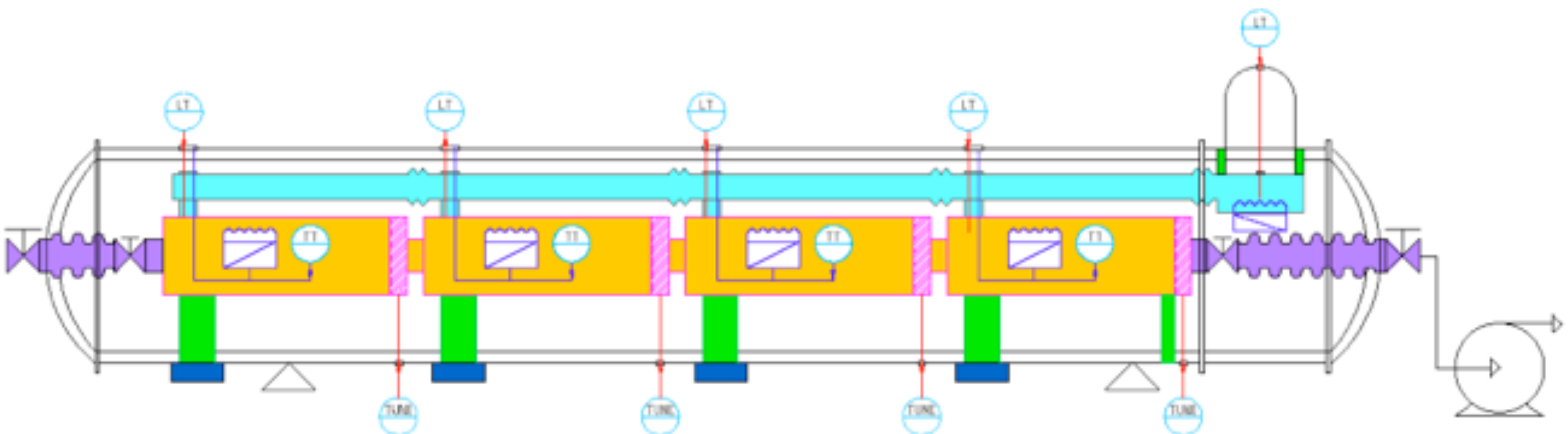


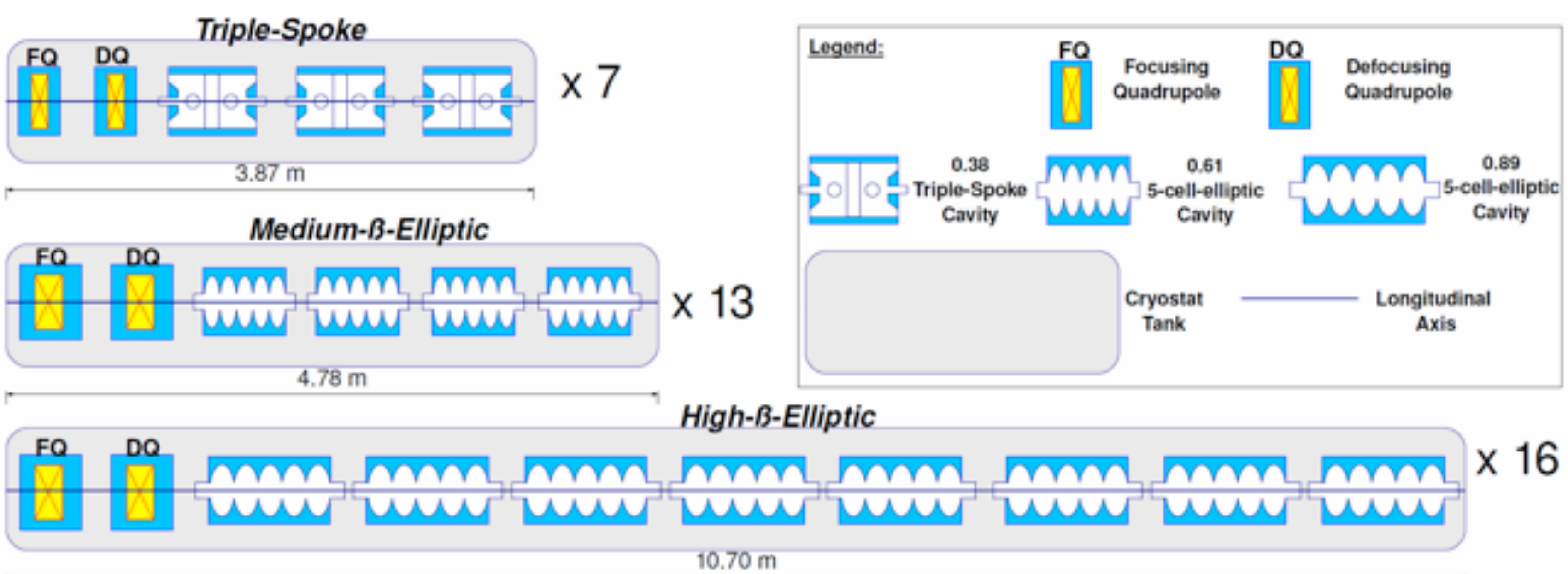
Recyclable
Carbon dioxide:
-15,000 ton/y

Technical issues

Cryomodules

continuous, segmented .... or hybrid?





SPL/ESS

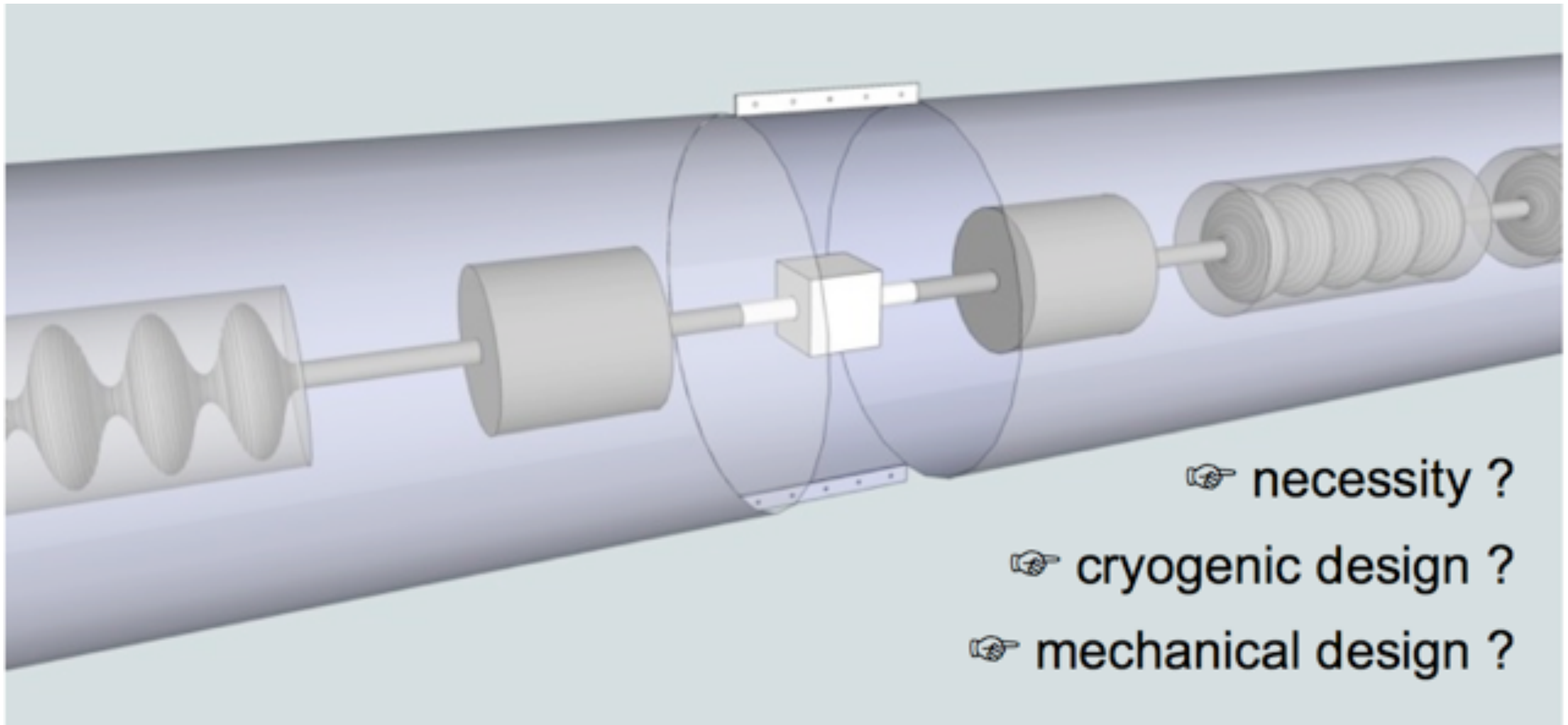
A "half" cryomodule is being built & will be tested at SM18 in collaboration with CERN.

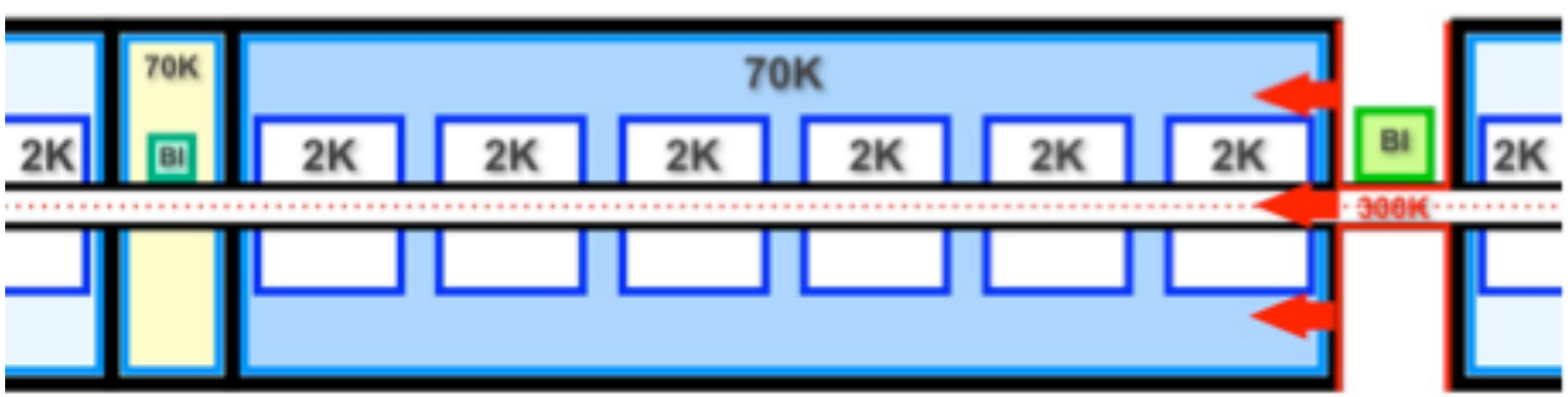
"2010 BASELINE"

assumed continuous elliptical cryomods, as shown at LEFT.

W. Hees, ESS, V. Parma, CERN & G. Devanz, CEA

Cryomodules



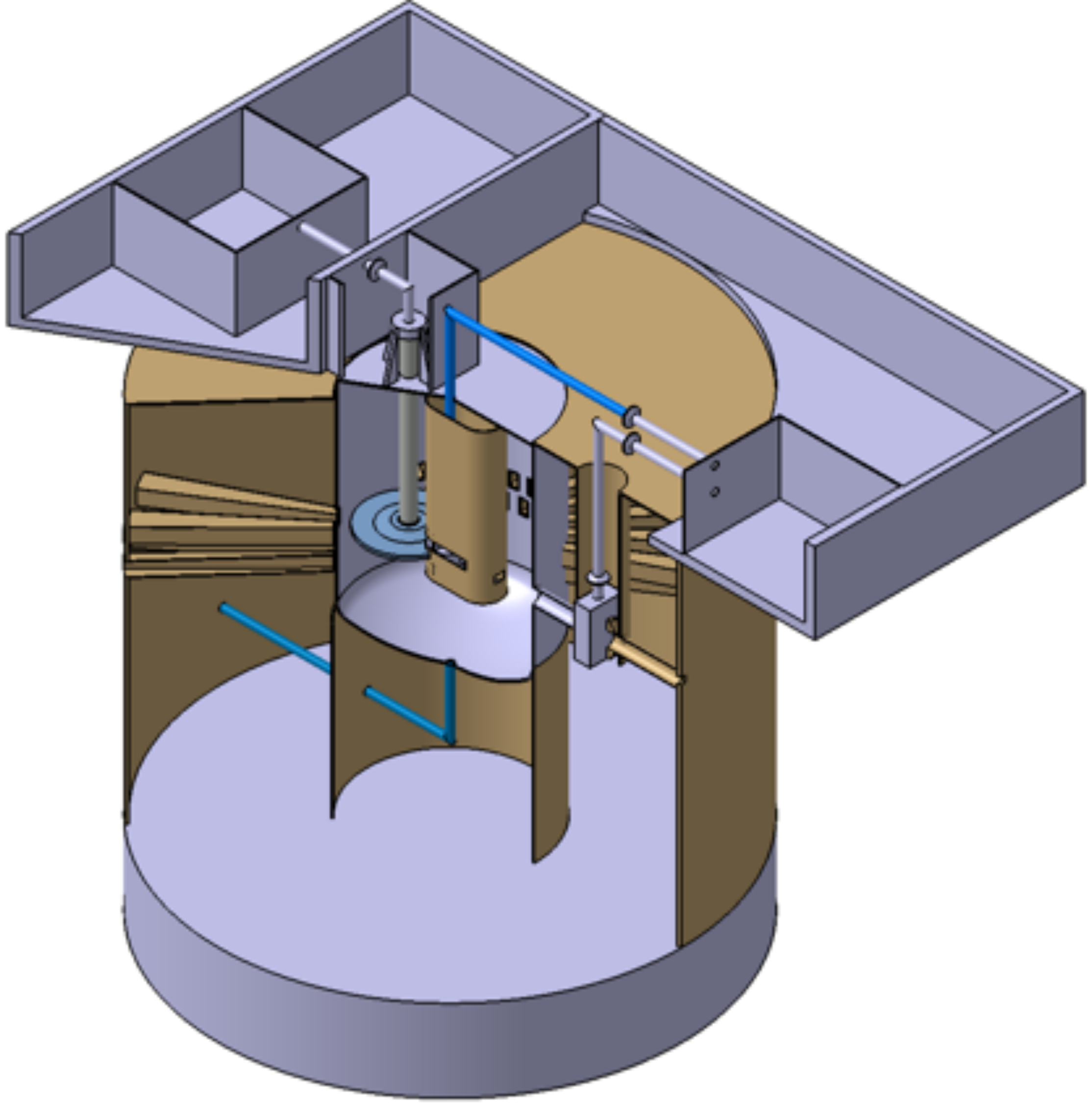


“2011 HYBRID” layout is under evaluation.

A ~70K sleeve encloses (most cold) interconects, reducing heat load.

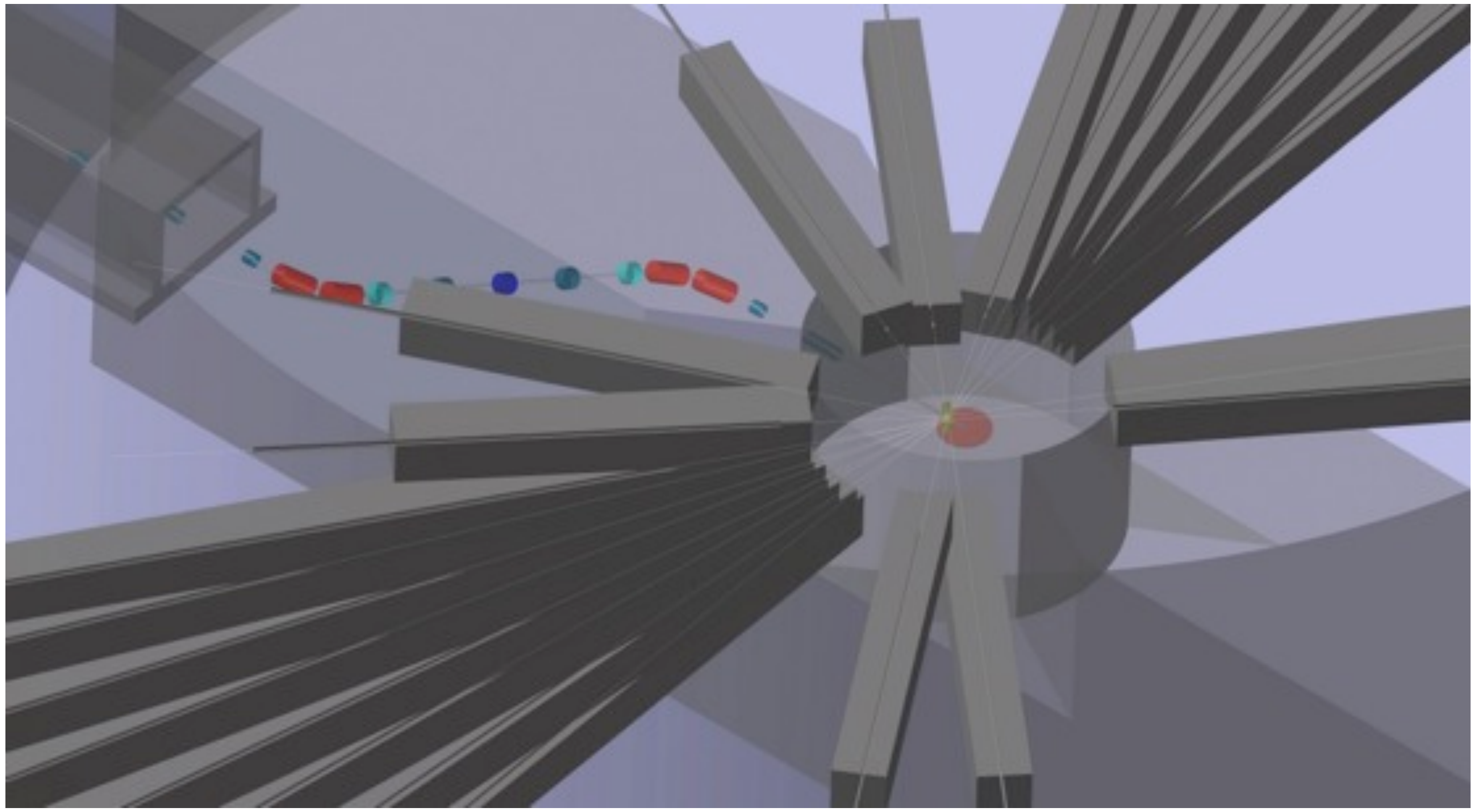
Some interconnects may be left warm, e.g. to simplify beam instrumentation.

Target-to-neutrons



Rotating tungsten disk target

- cooled by helium
- diameter 1.50 m
- thickness 0.08 m
- rotation rate 0.5 Hz

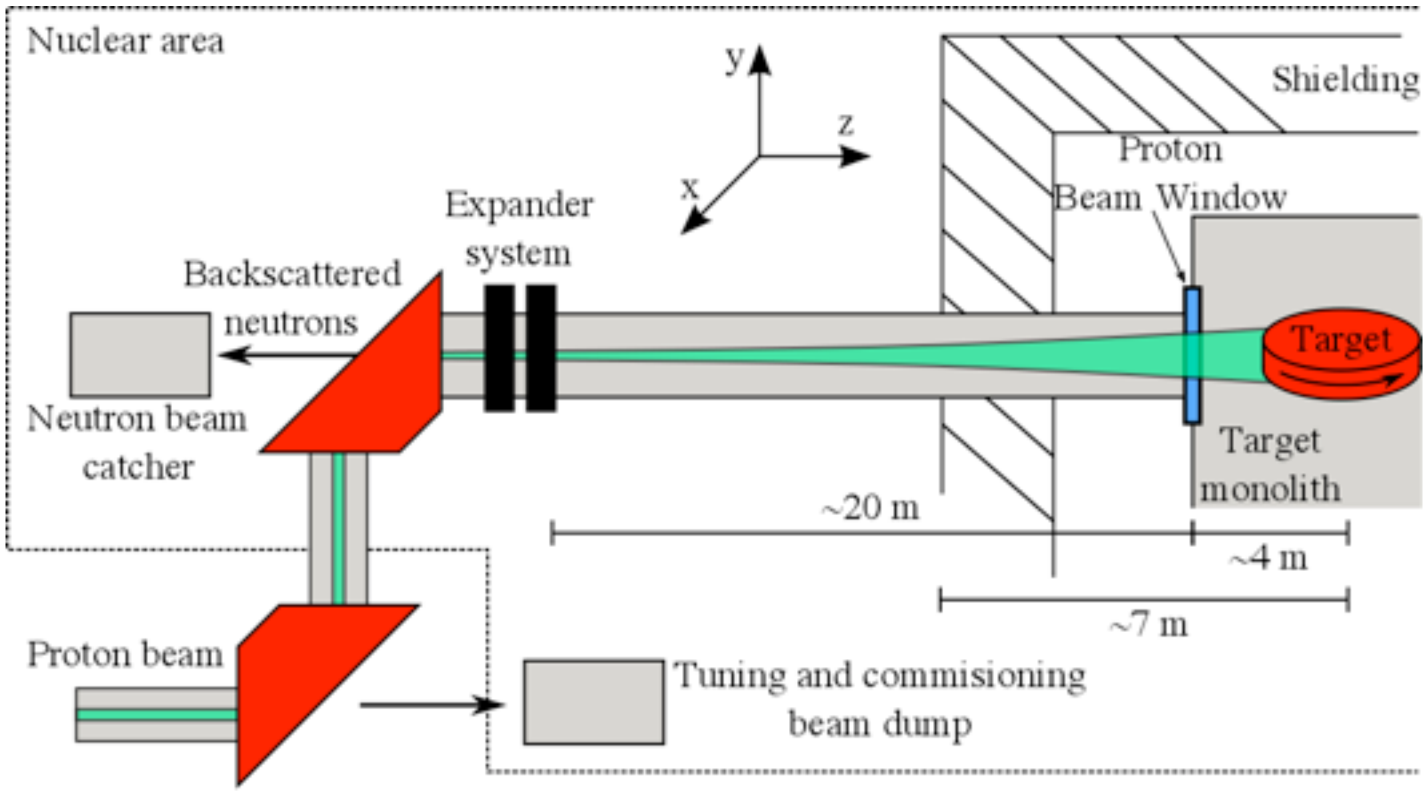


Target-to-neutron-lines

- 22 neutron lines
- Not all instruments commissioned on Day 1
- Moderators ~10 cm above & below target

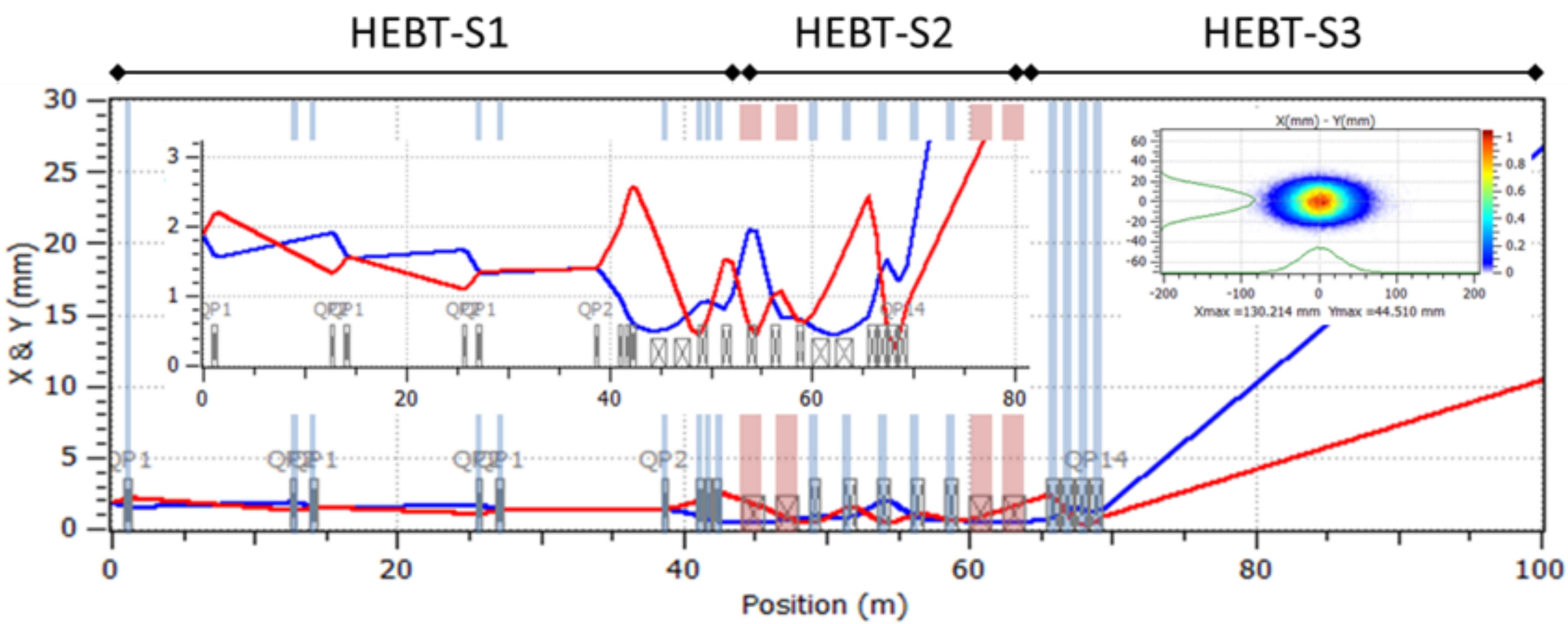
http://esss.se/linac/Parameters.html

Target-to-accelerator

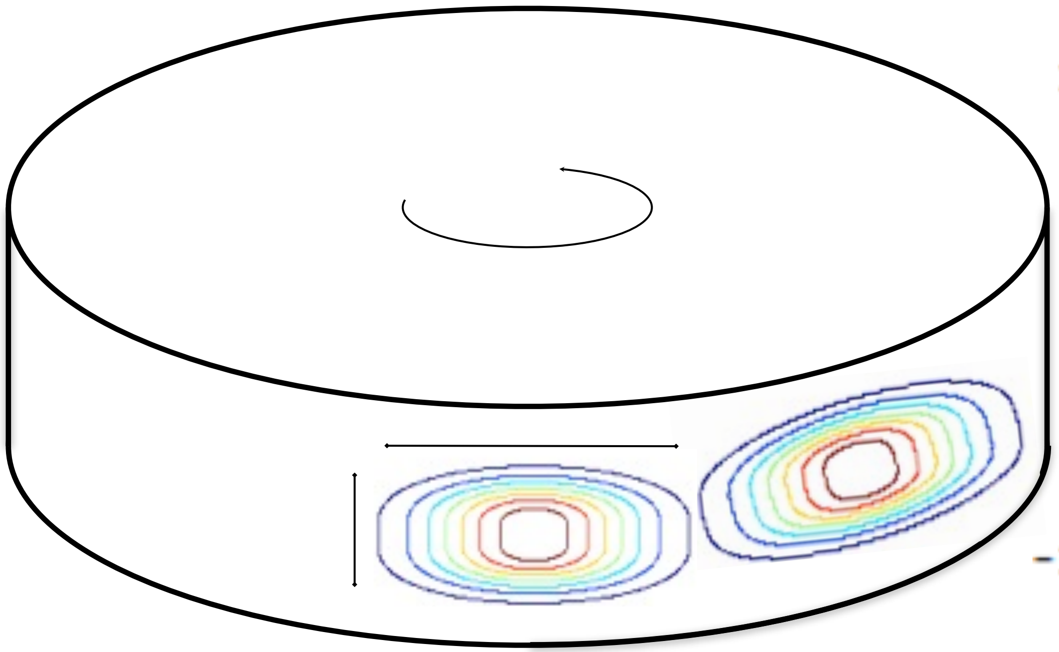


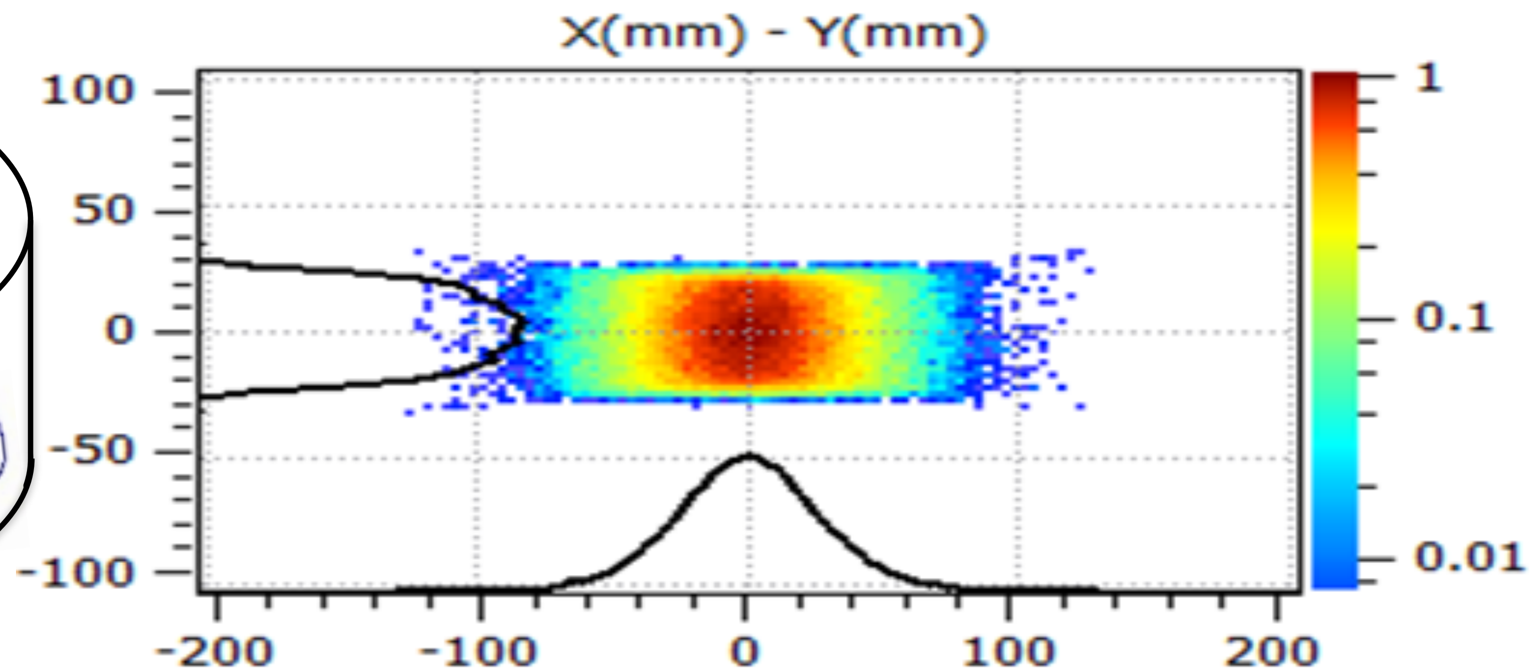
Accelerator-to-Target

- Rise from -10 to +1.6 m
- Tune-Up Dump
- Beam windows
- Distributed systems
- Beam diagnostics
- Protection systems



Beam shape on target





Target lifetime is expected to depend critically on:

- maximum peak current density
- intensity gradient
- extent of tails

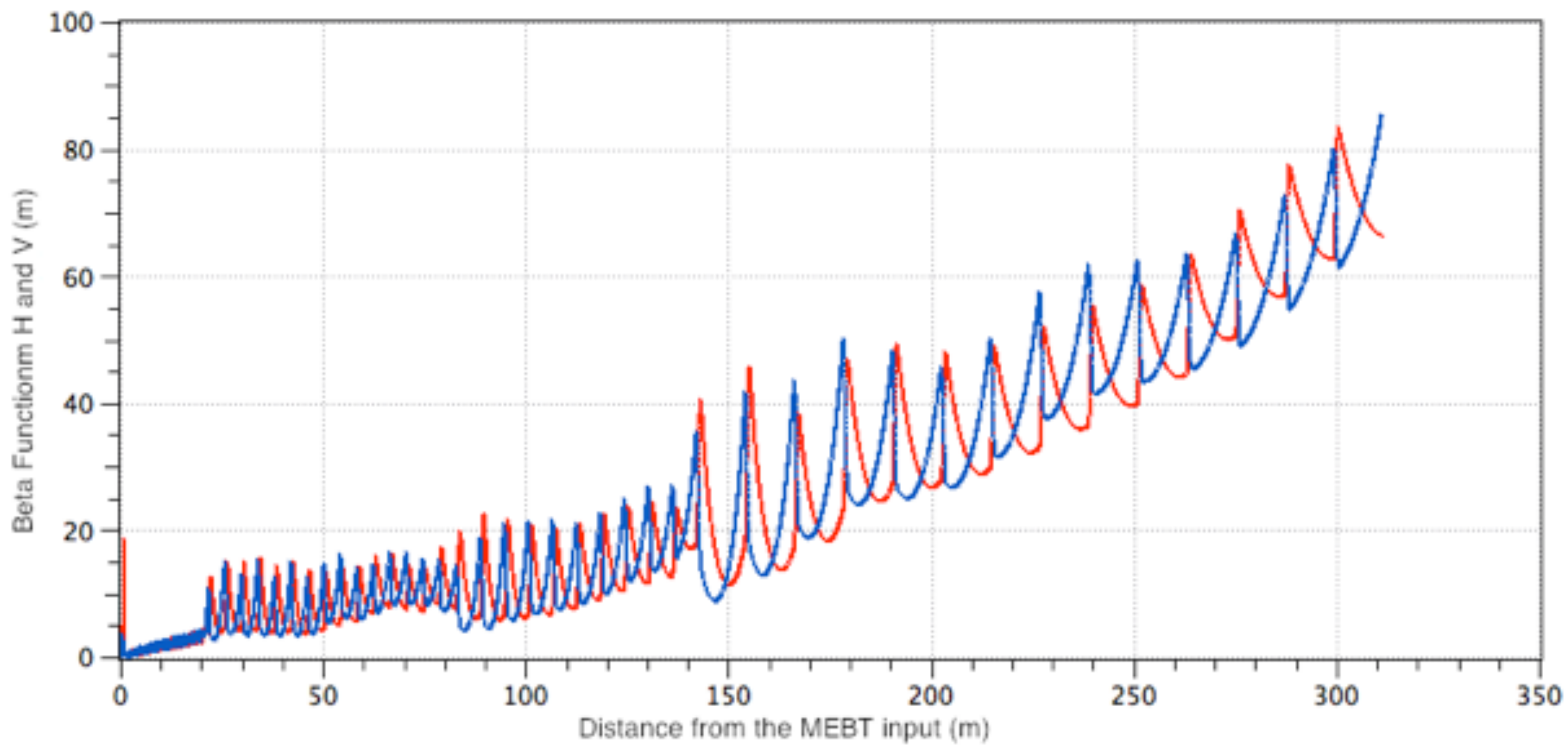
Horizontally: Overlapping gaussians are ok

Vertically: Flatten distribution with octupoles, without tails

Octupoles reduce the peak current density by 60%

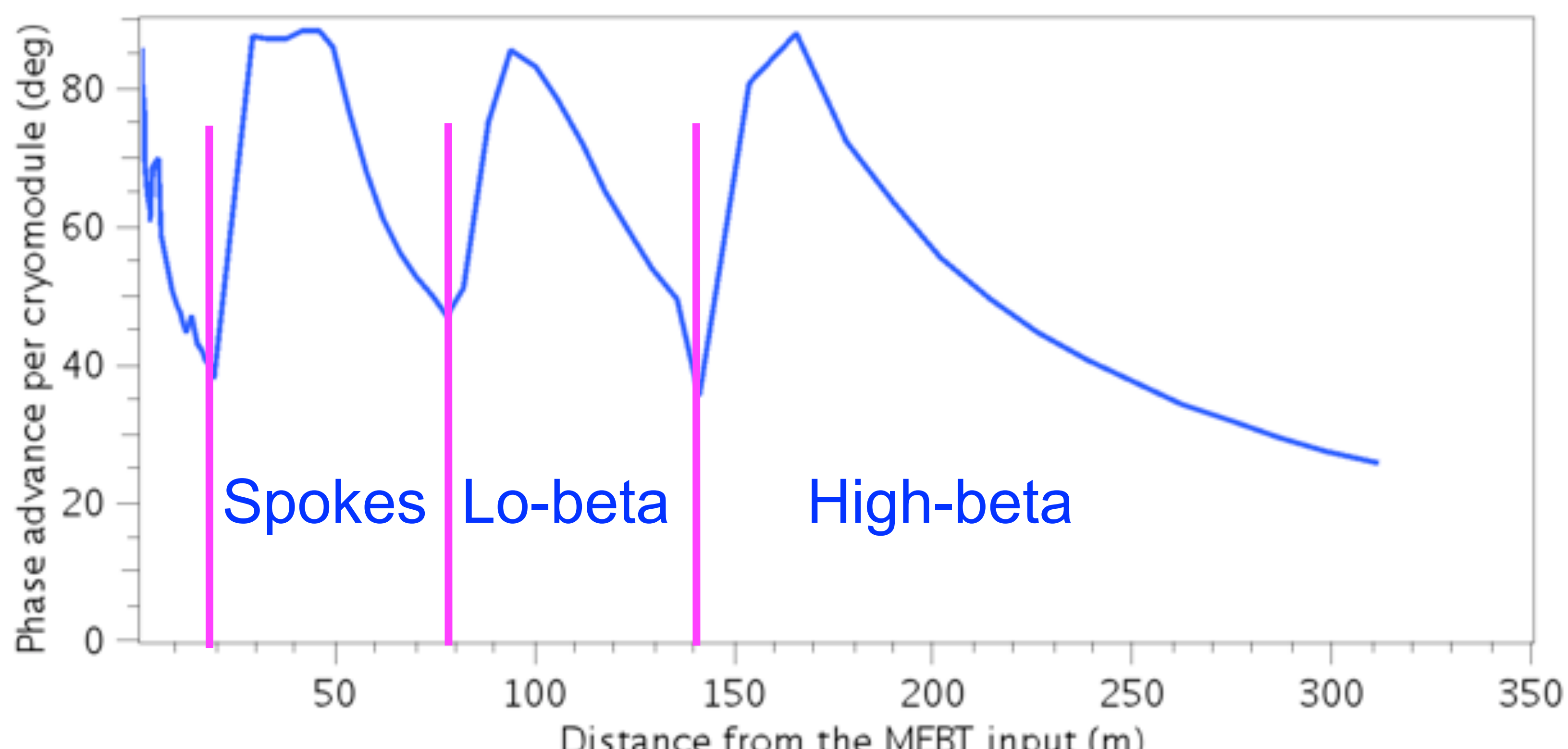
A.Holm, S.Pape-Møller, H.Thomsen

SRF linac optics



Transverse beta functions (TOP) increase smoothly

- weakening doublets
- ~constant beam size
- little emittance growth

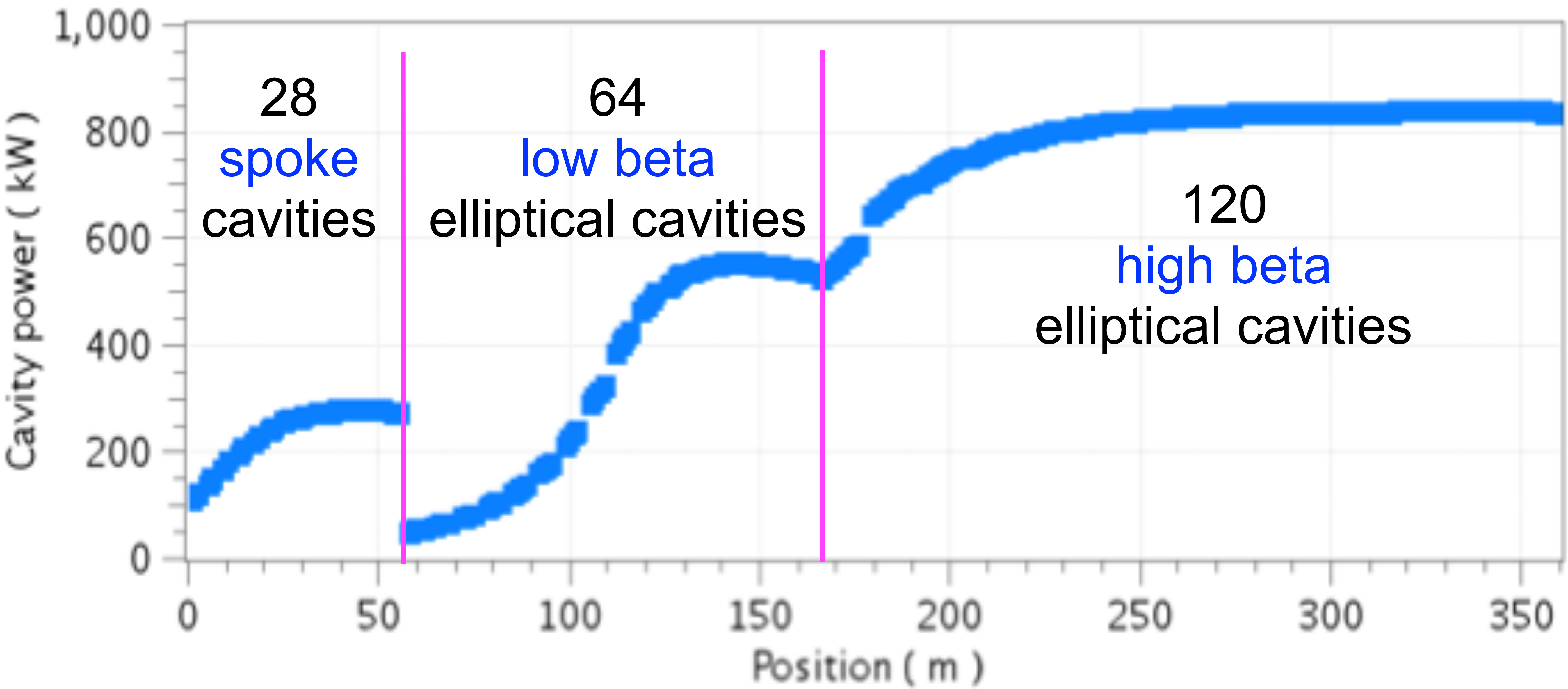


Longitudinal optics (BOTTOM) represented by phase advance rate

- matched transitions
- one klystron per cavity

M. Eshraqi, H. Danared, K. Rathsman

Longitudinal strengths



How to reconcile these idealized optics with the real world?

- SNS experience with a broad range of as-built cavity gradients
- ILC planning for a +/-20% range of gradients

Quality assurance, production testing, sorting, re-tuning, simulating?

Beam losses

Radio-activation is unacceptable from losses larger than about 1 W/m.

Intra-beam stripping is plausibly an important source of beam losses in H- linacs like the SNS (0.2 W/m) - but not in the H+ ESS !

Other potential beam loss sources:

1. Space charge resonances
2. Transverse overfocusing
3. Uncollimated low energy beam halo

Attaining the ability to confidently predict the relative importance of loss mechanisms is a fundamental challenge to our ability to design multi-MW proton linacs.

Resolve by 1) simulation & theory, 2) experiment (eg, SNS) ......

End-to-end simulations

of course, but what is the question?

1) Optics design & tuning strategies: integration by beam
   - lengths & strengths, optics matching
   - diagnostics & correctors, algorithms
   - on-line & off-line from one single model

2) Multi-particle pushing:
   - does the emittance blow up, do tails grow?
   - collimation
   - Beam losses: fundamental challenge - power limit?

3) Contingency: real-time production line response
   - move risk from manufacturer to ESS (cf XFEL)

4) Upgradability: the cost of preservation
   - Power, non-neutron scattering uses, parasitic extraction

5) Reliability: longer term contingency response
   - Synergy with ADSR?

RF issues

Higher Order Modes

- There is risk in NOT damping, & also IN damping HOMs
- HOM couplers will be installed if ongoing studies indicate the need
- Could be instrumented to measure transverse displacements

Field Emission & Multipacting

- SNS experience indicates that FE & MP may limit cavity performance
- Excessive power into HOM electronics, via thermal detuning?
- A simulation campaign has been launched

Low Level RF

- Protons: semi-relativistic speeds cause phase & amplitude errors to accumulate along the linac
- Investigations (eg of modulator ripple & droop) are in progress

Potential upgrades

The mandate is to build a 5 MW accelerator!

The most likely scenario is a power upgrade to higher power, with maintaining bunch time structure

- towards 7.5 MW via current &/or energy, from 50 mA & 2.5 GeV

How this can be prepared within the present 5 MW baseline?

- the additional cost will be estimated & made apparent in the costing of the 5 MW baseline

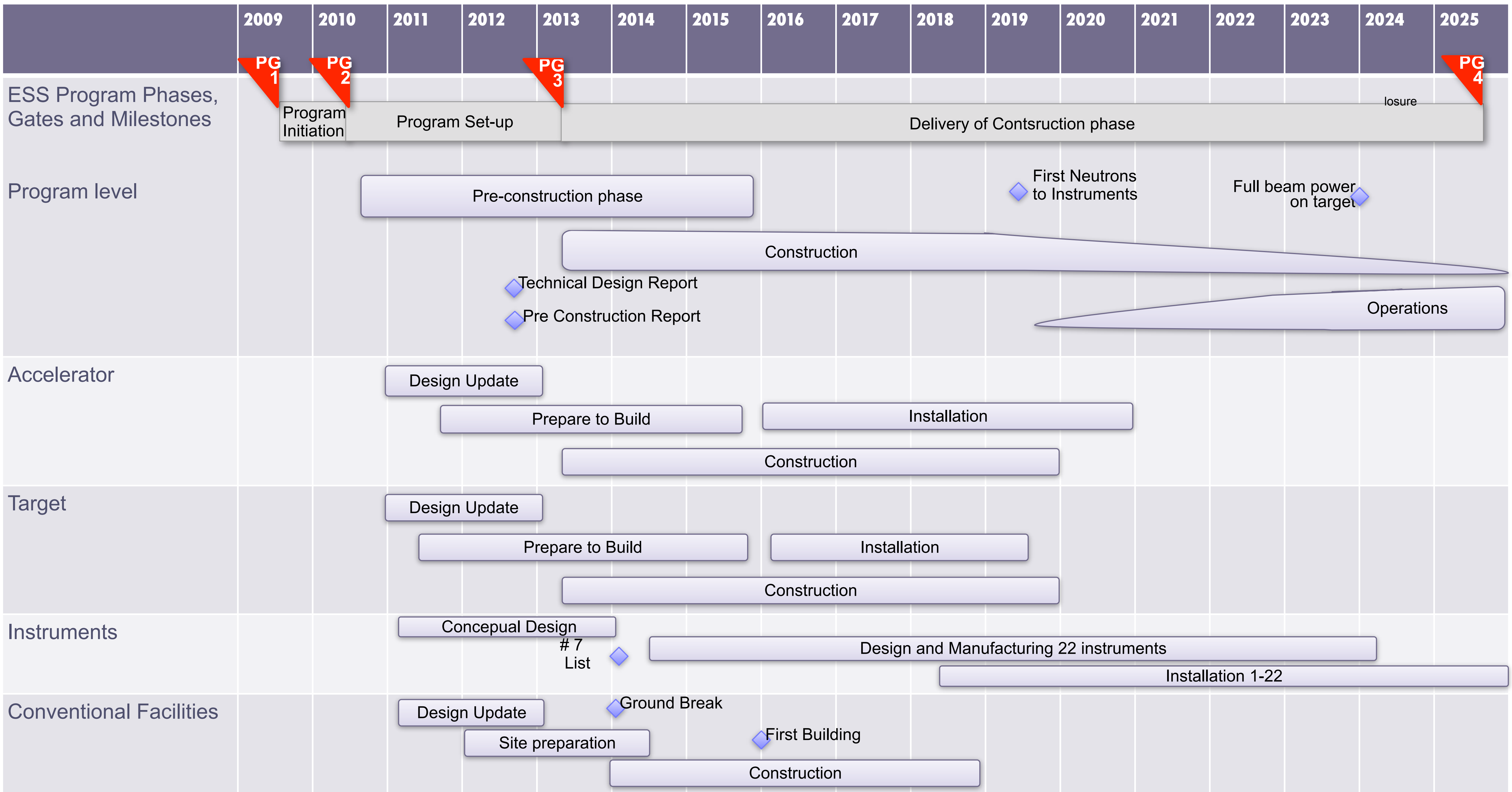
NO second “full power” Target Station !

- but secondary proton extraction lines may be possible?

NO H- injection or short pulses, or accumulator ring !

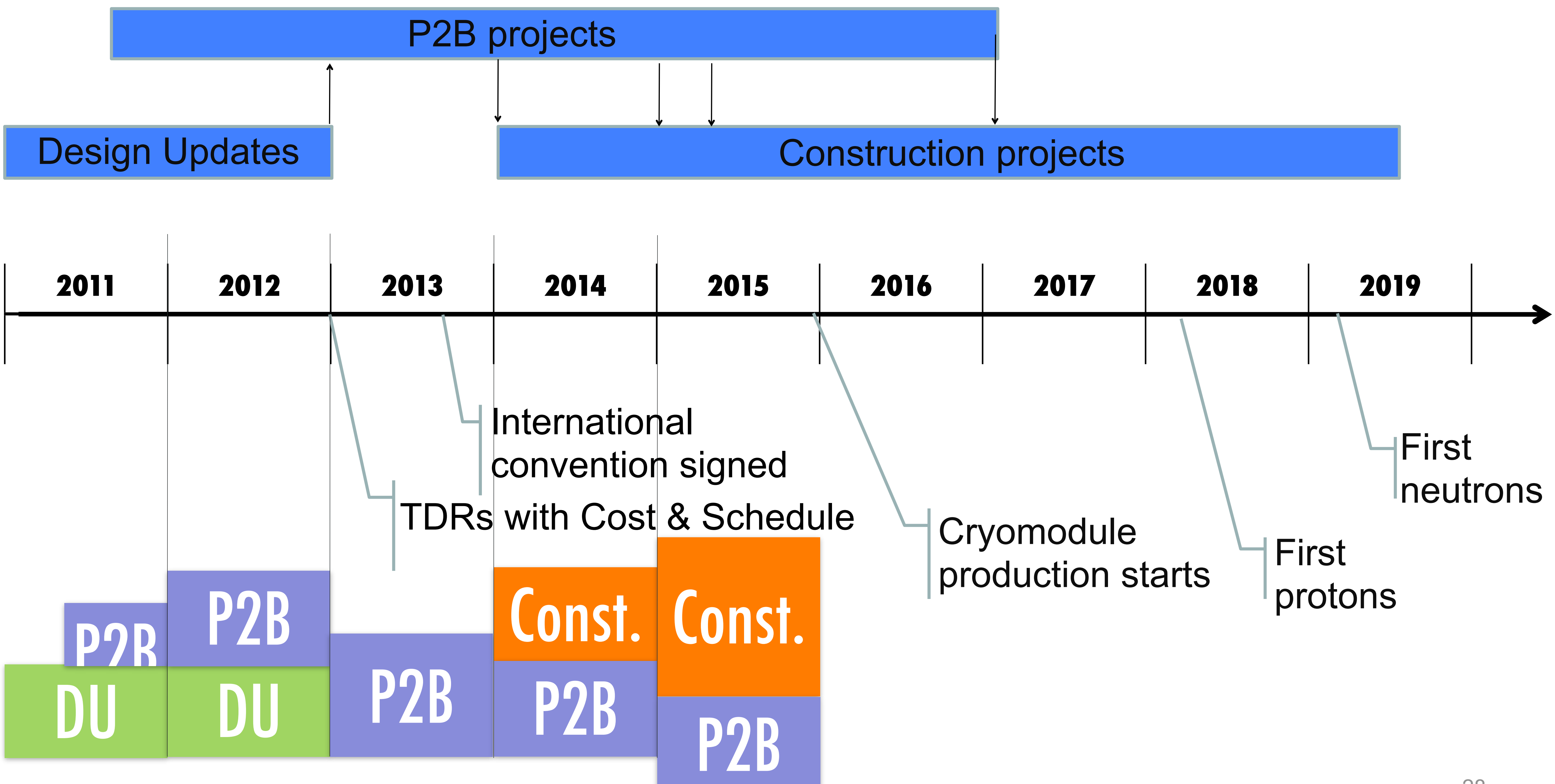
Organization & planning

ESS Master Programme Schedule



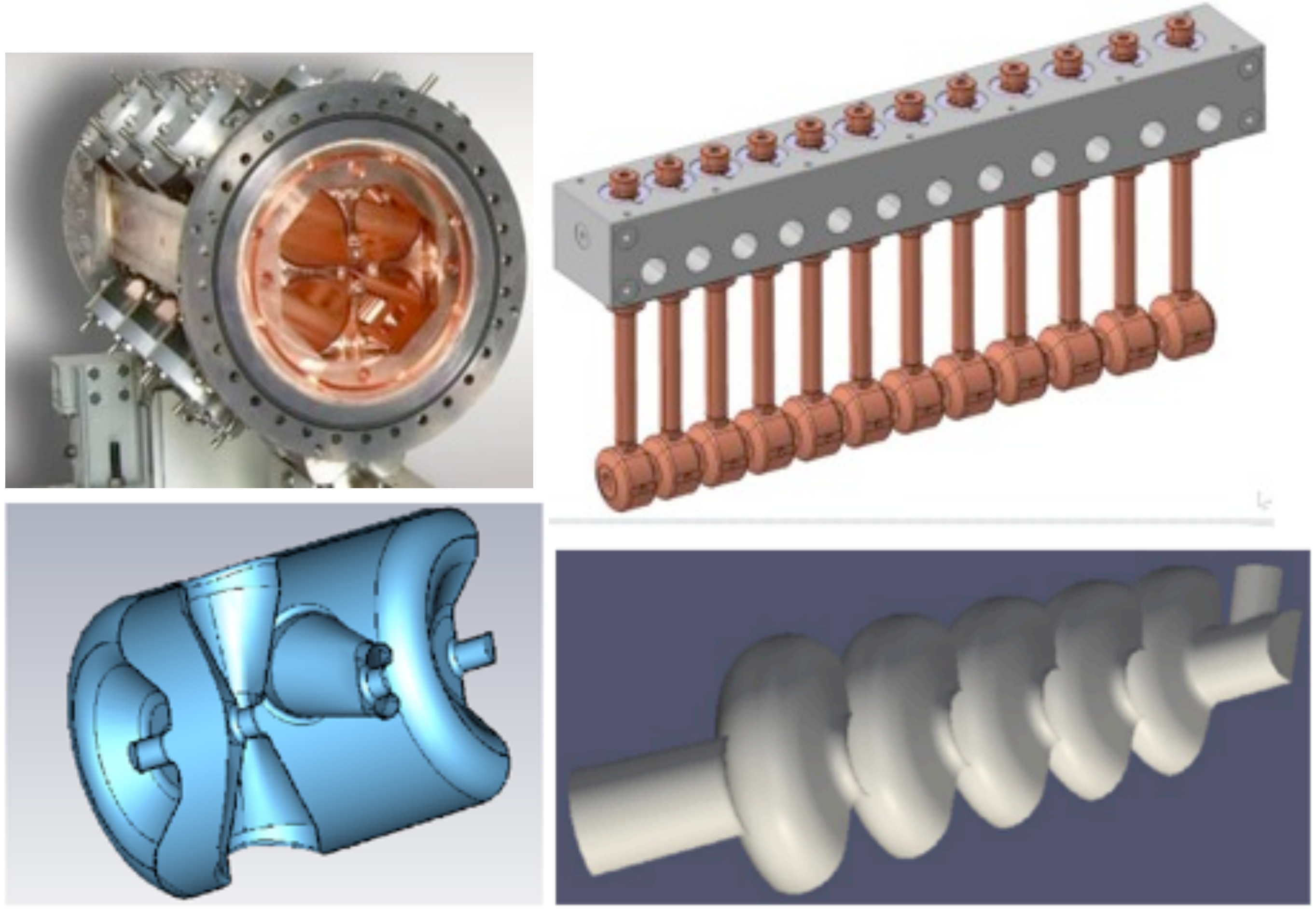
Current activities

Prepare-to-Build (P2B) provides 1) Prototyping & 2) Engineering Design Reports, in smooth transitions from design to construction.



The accelerator collaboration

17 member states so far ...



NC linac: Ion source (INFN), RFQ (CEA), MEBT (Bilbao), DTL (INFN)
SC linac: Spoke Cavities (CNRS), Elliptical cavities (CEA)
High Energy Beam Transport: Aarhus university
RF sources: High-power (Uppsala U), RF regulation, LLRF (Lund U)
Utilities: power, network, cooling, etc (Tekniker)

Test stand strategy

704 MHz test stand for SC elliptical cavities and a cryomodule

Upgrades of CERN, CEA and Uppsala test stands

- Uppsala: RF source, control & distribution (energy aspects)
- ESS is contributing with a modulator to the CERN test-stand
- IFMIF test stand extended at CEA

Possible use of XFEL infrastructure & test stands at DESY & CEA during ESS construction

352 MHz test stand for SC spoke cavities and cryomodules

One test stand at CEA

One test stand under construction at IPNO in Paris

Test area for Ion Source development exists in Catania

Accelerator Division expansion

Sept 2011 → Dec 2012

Technical staff	**22 → 38**
RF systems & power supplies	4 → 9
Beam physics & magnets	5 → 6
Beam instrumentation	3 → 7
Cryogenics & vacuum	3 → 5
Controls & scientific computing	3 → 6
Administration & project support	4 → 5

Recruitment is very much in progress!

Summary

EUROPEAN SPALLATION SOURCE

1. The European Spallation Source will be built in Lund.
2. The design will ensure a long life with many upgrades.
3. The accelerator design, prototyping & construction is being performed in a collaboration.
4. The energy aspects of the accelerator complex are very important.
5. We look forward to welcoming more collaborators to ESS !

Many thanks to all members of the emerging ESS accelerator collaboration, and to SNS !