Accelerator Physics and Technology for ESS

EUROPEAN SPALLATION SOURCE

Håkan Danared

IPAC 2012, New Orleans, 23 May 2012

Acknowledgements

S. Gammino
S. Bousson
G. Devanz
S. Pape Møller
R. Ruber

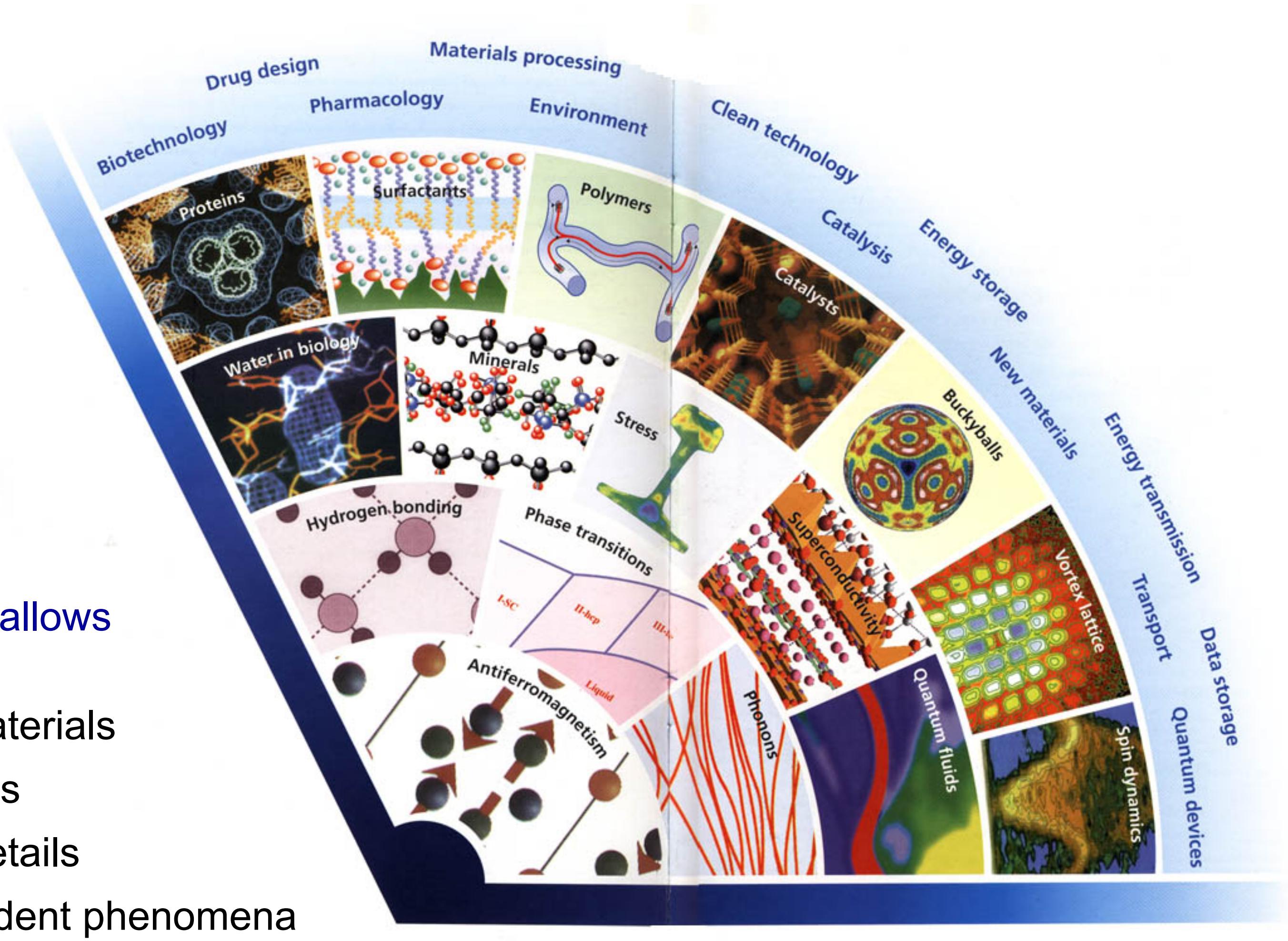
M. Lindroos
S. Peggs
W. Hees
A. Jansson
D. McGinnis
G. Trahern

Persons mentioned on the slides, plus co-authors, whose IPAC posters and papers I have taken material from

Collaborators at ESS in Lund and at our European partners

Neutron Science and Neutron Flux

Complexity/
Count-rate

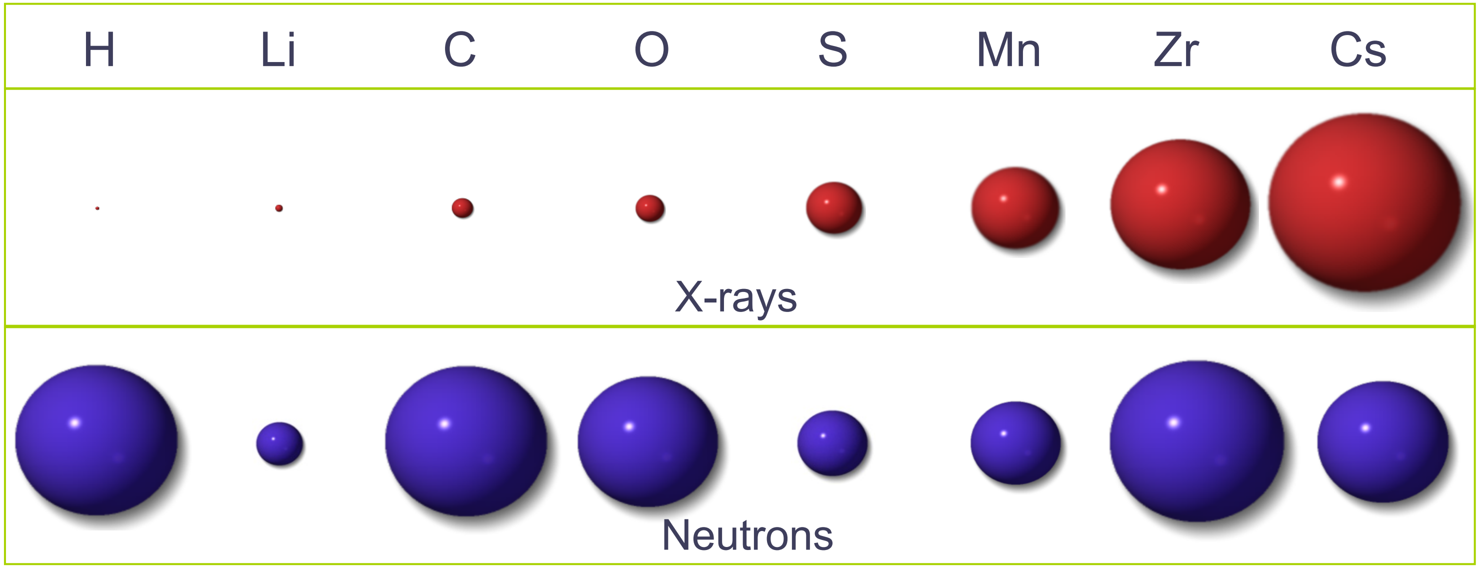


ESS intensity allows studies of

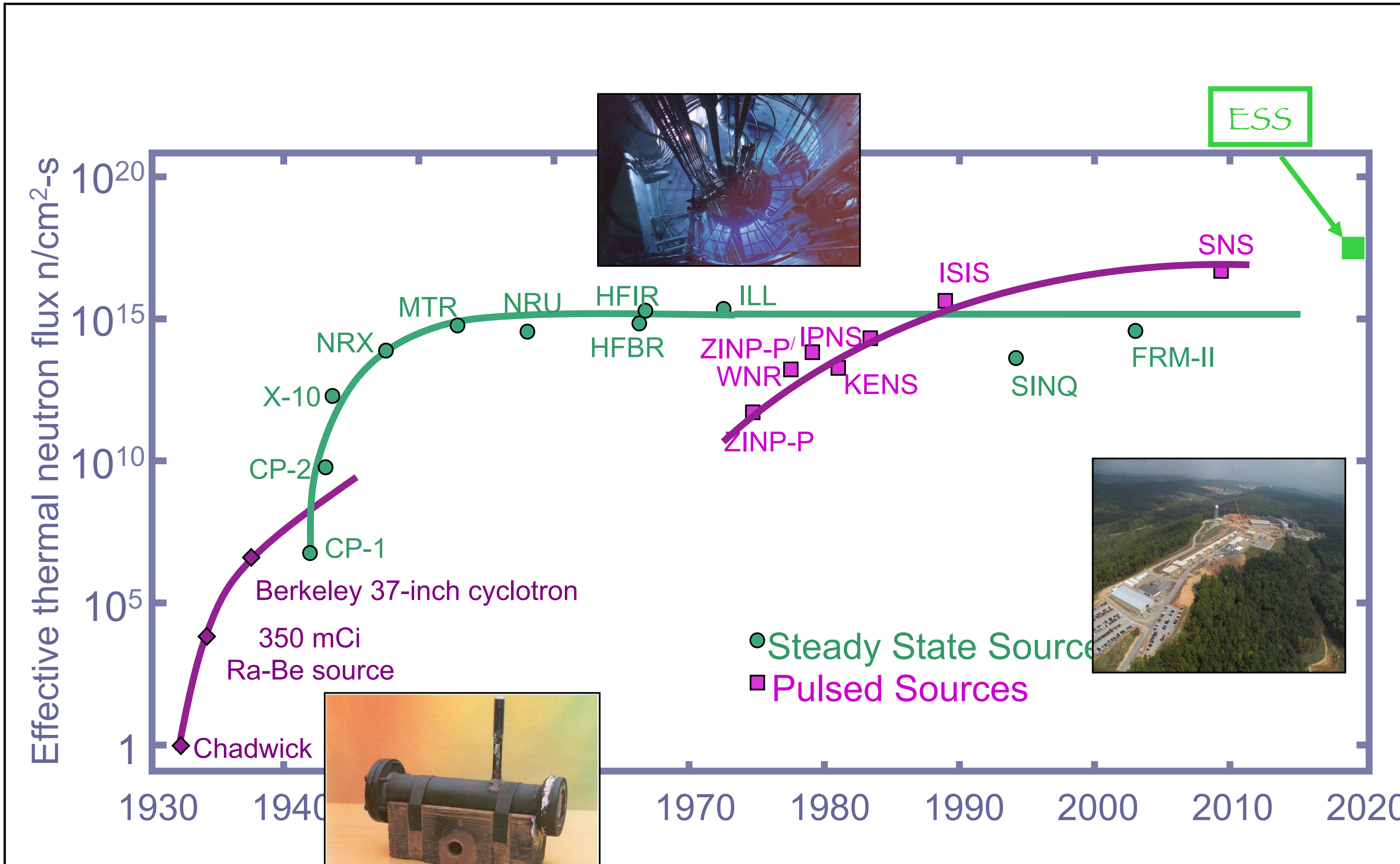
– Complex materials
– Weak signals
– Important details
– Time dependent phenomena

Details/Resolution

Neutron See the Nuclei…



Evolution of Neutron Sources



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

International collaboration

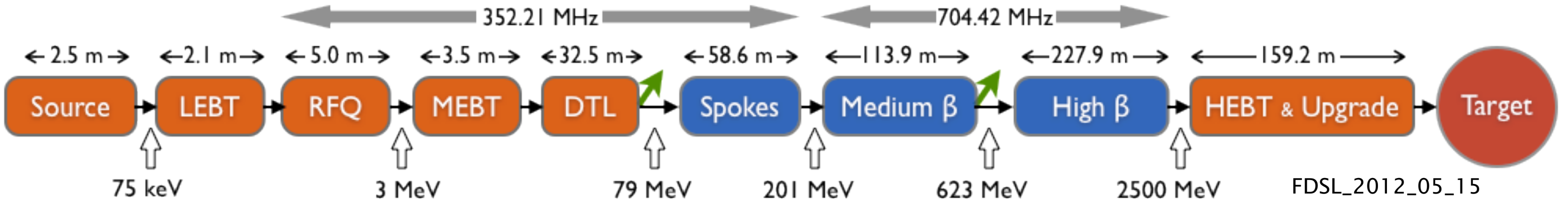
Sweden, Denmark and Norway cover 50% of construction cost

Remaining 50% from European partners

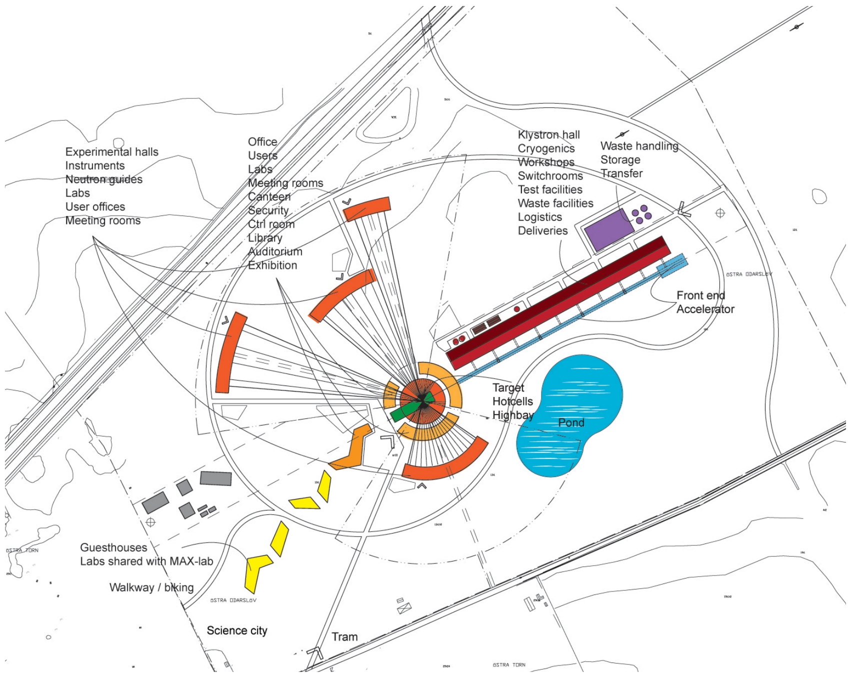
Letters of intent from 17 European states

Multilateral MoU for pre-construction signed in Paris 11 Feb 2012

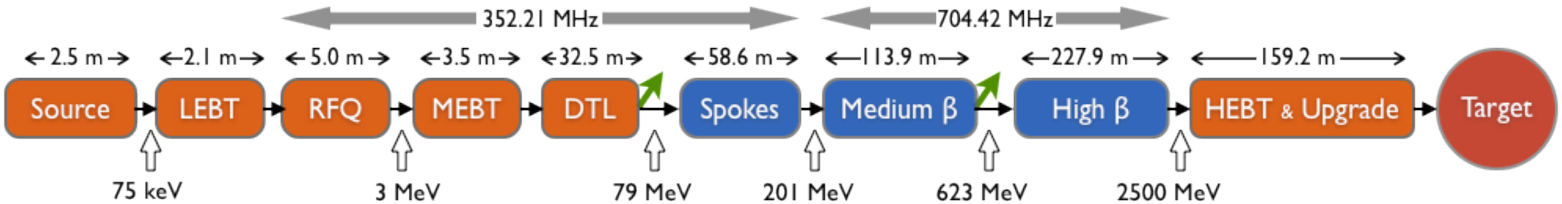
ESS Linac Parameters



Particle species	p
Energy	2.5 GeV
Current	50 mA
Average power	5 MW
Peak power	125 MW
Pulse length	2.86 ms
Rep rate	14 Hz
Max cavity surface field	40 MV/m
Operating time	5200 h/year
Reliability (all facility)	95%



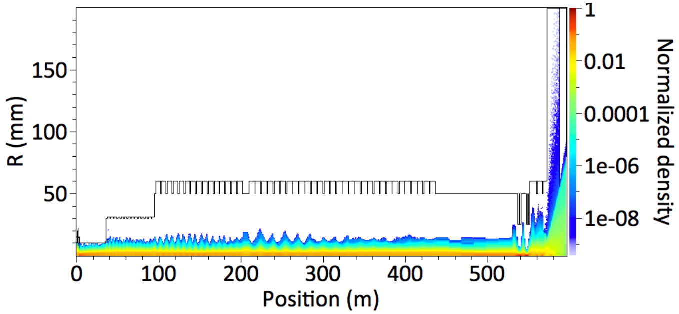
Linac Layout



	Lab	E_{out} (MeV)	$Beta_{out}$	Length (m)	Temp (K)	Freq (MHz)
Ion source + LEBT	Catania	0.075	0.01	4.6	300	–
RFQ	Saclay	3	0.08	5.0	300	352.21
MEBT	Bilbao	3	0.08	3.5	300	352.21
DTL	Legnaro	79	0.39	32.5	300	352.21
Spoke cavities	Orsay	201	0.57	58.6	2	352.21
Medium-beta ellipticals	Saclay	623	0.80	113.9	2	704.42
High-beta ellipticals	Saclay	2500	0.96	227.9	2	704.42
HEBT	Aarhus	2500	0.96	159.2	300	–

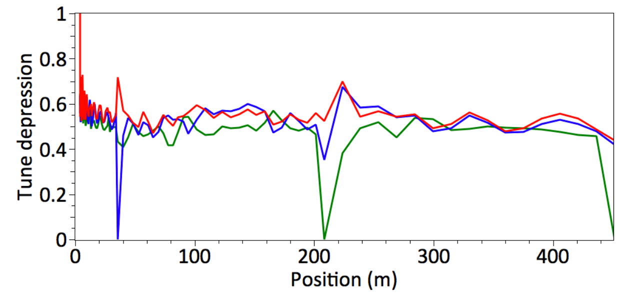
	Spoke resonators	Medium-beta ellipticals	High-beta ellipticals
Cells per cavity	3	5	5
Cavities per cryomodule	2	4	4
Number of cryomodules	14	15	30

Beam Dynamics

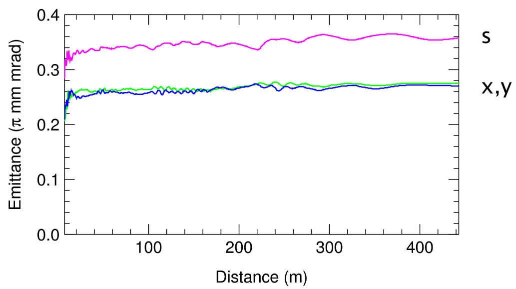


Beam density from RFQ to target

M. Eshraqi, THPPP085



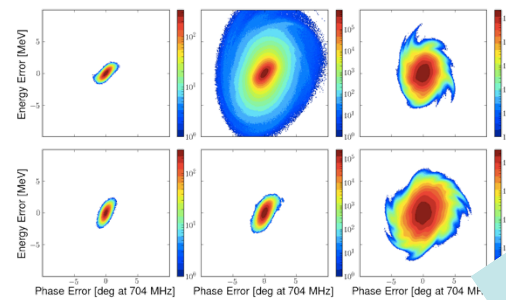
50 mA gives large tune depression!



Small emittance growths in all three planes

... although full beam size, including halo, is more important than RMS emittance

Maximum 1 W/m beam losses allowed

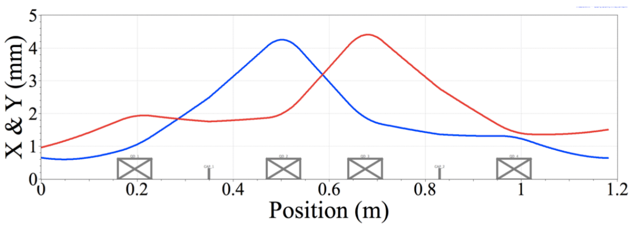


R. Ainsworth

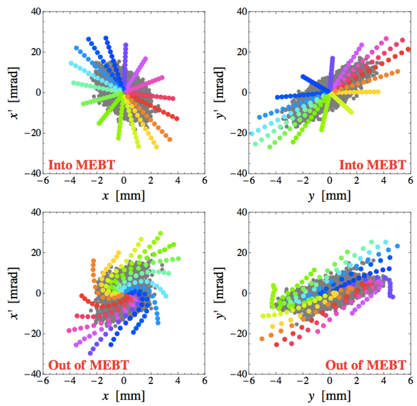
Long. phase space with SOMs in medium betas
Upper row "old" linac layout, lower current layout
Left: input distribution
Middle: with SOMs (4π/5 etc.)
Right: uniform RF errors

EUROPEAN SPALLATION SOURCE

Beam Halo and Collimation



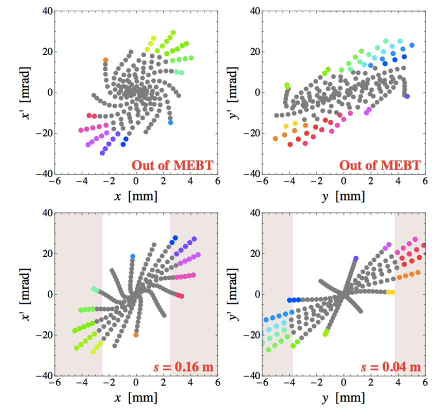
Simplified MEBT with four quadrupoles



Beam core (grey) plus halo (colour) added ”by hand” (0.5σ, 1σ, ..., 6σ)

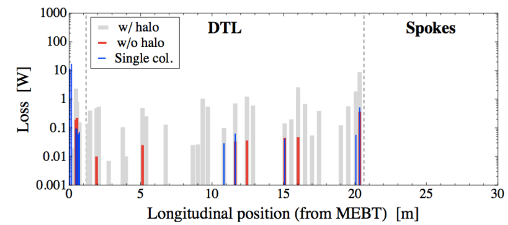
Into MEBT (top) and out of MEBT (bottom)

R. Miyamoto,
MOPPD076



Particles outside of 5σ (colour) out of MEBT (top)

A position at the beginning of the MEBT can be found where these particles have large x or y and can be collimated (bottom)

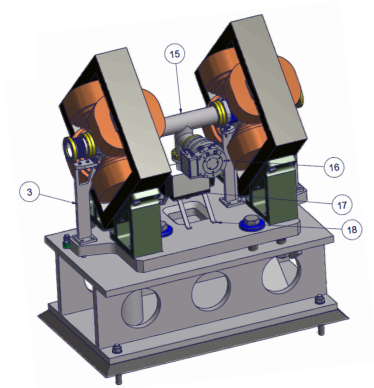


Beam losses in DTL and spokes with no halo (red), with halo (grey), with halo+coll (blue)

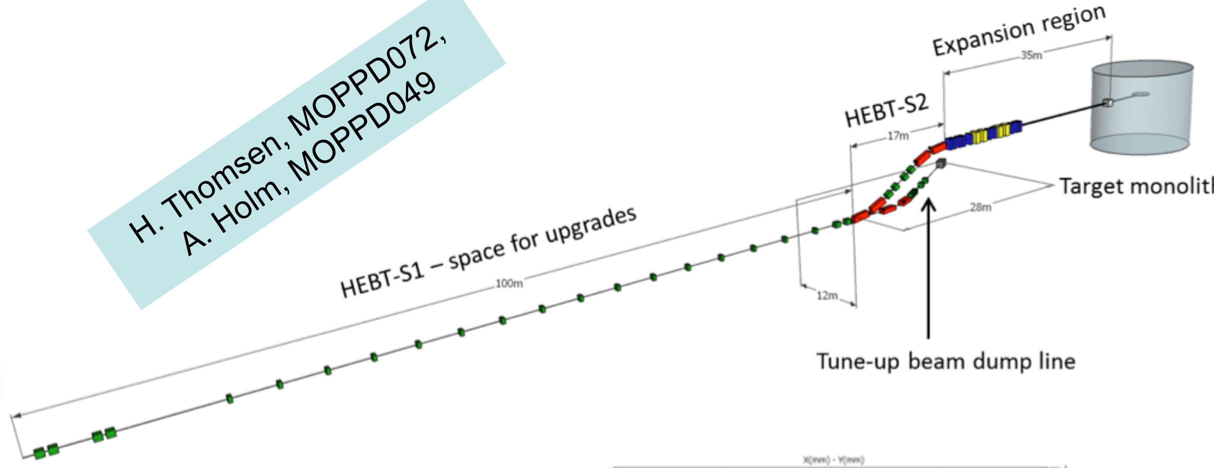
Work in progress...

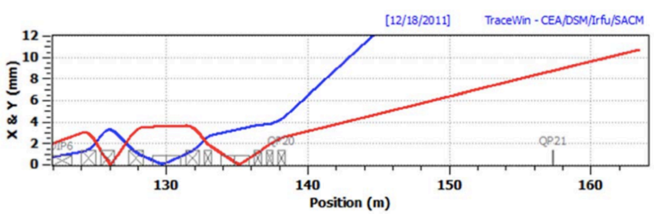
High-Energy Beam Transport

H. Thomsen, MOPPD072,
A. Holm, MOPPD049

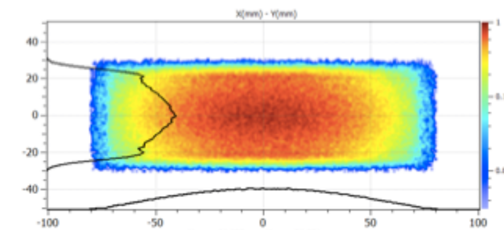


Quadrupole doublet
for linac and HEBT





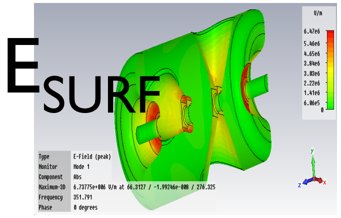
Beam expansion on target with quadrupole magnets plus two octupoles

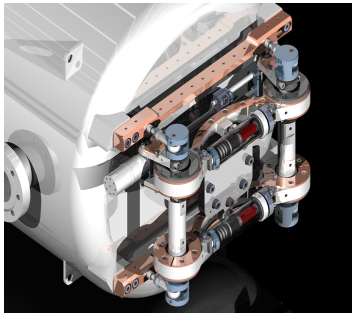


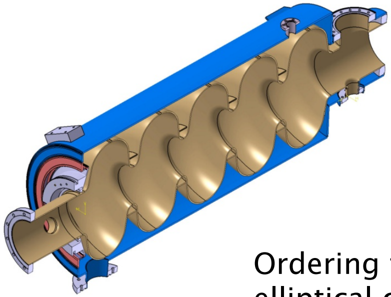
Example of beam profile on target (160 mm × 60 mm) with a peak current density of 49 μA/cm²

Fixed collimator outside proton-beam window with design depending on beam halo and acceptable peak current density

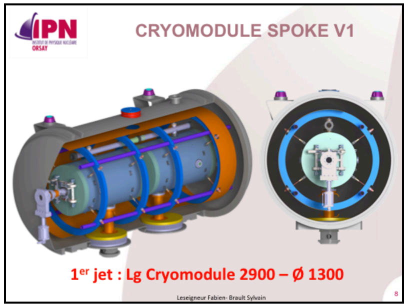
Cavities and Cryomodules

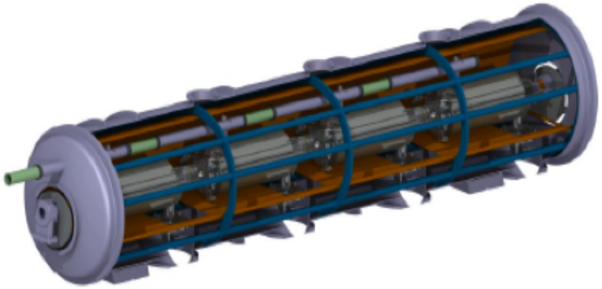






Ordering for high-beta elliptical cavities on-going at CEA, Saclay

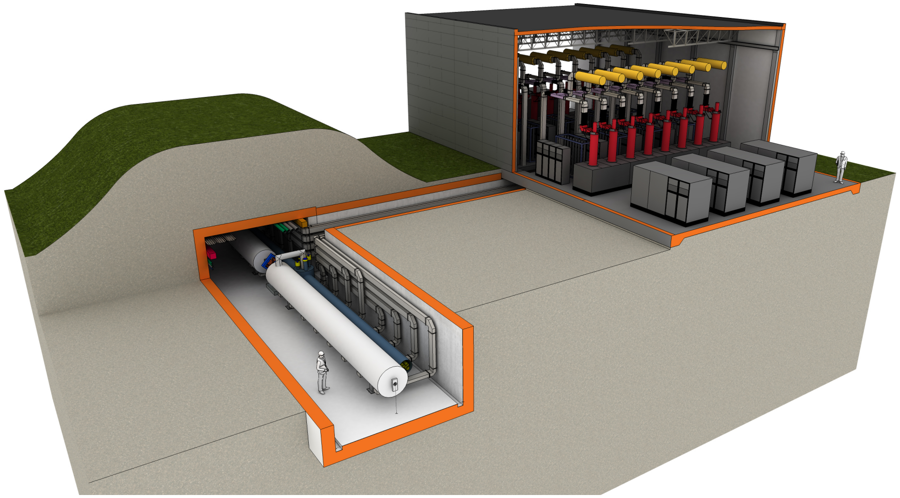




Spoke cavities and cryomodules:
Design is in progress at IPN, Orsay,

Elliptical modules: Design is in progress at CEA, Saclay and IPN, Orsay. In addition R&D is done in collaboration with CERN

RF Systems



	Frequency (MHz)	No. of couplers	Max power (kW)
RFQ	352.21	1	900
DTL	352.21	4	2150
Spokes	352.21	28	280
Medium betas	704.42	60	560
High betas	704.42	129	850

RF regulation with 30% overhead

Adaptive low-level feed-forward algorithms and low-gain feedback

High-bandwith piezo tuners on superconducting cavities

R. Zeng, THPPC083,84
A. Johansson, WEPPP093

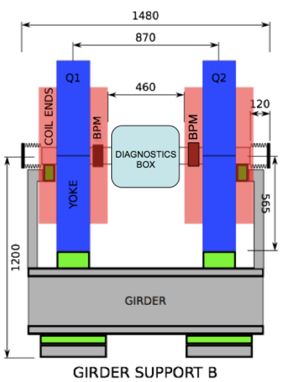
Main features:

- One RF power source per resonator
- Two klystrons per modulator for ellipticals
- Pulsed-cathode klystrons for ellipticals, DTL and RFQ
- Gridded tubes (IOTs) for spokes
- Klystrons grouped across RF gallery
- Bundled waveguide layout

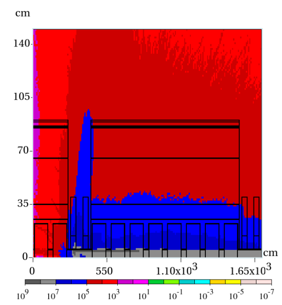
Beam Instrumentation

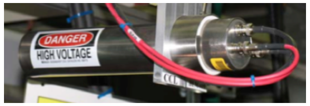
	Beam loss	Beam position	Beam current	Transv. profile	Emitt.	Bunch length	Faraday cup	Halo
LEBT			2	3	1		1	
RFQ								
MEBT		4	2	3	1		1	2
DTL	30	3	2					
Spoke cavities	45	30	1	4	2	3		tbd
Medium-beta ellipticals	30	20	1	4		3		tbd
High-beta ellipticals	42	28	1	4		3		tbd
HEBT	22	22	1	5		3		tbd

Preliminary system count



Quadrupole doublet on girder with BPMs and diagnostics box





Beam-loss simulations

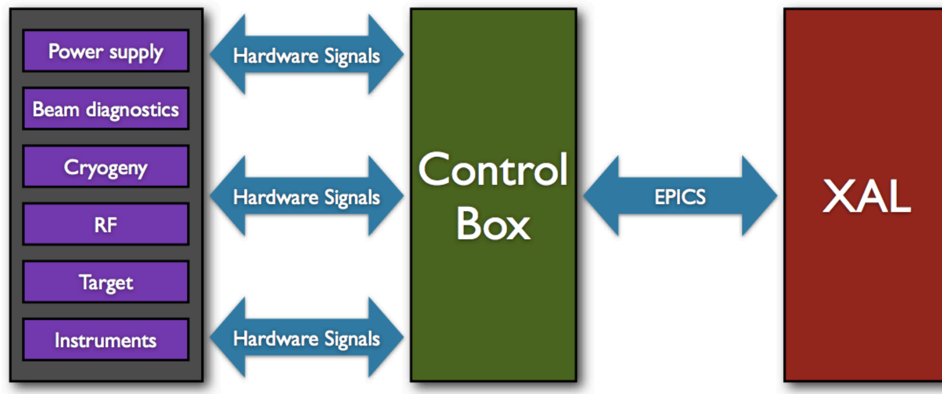
A. Jansson, MOPPR045

Integrated Control System

Decision to have a single integrated control system for ESS:
- EPICS-based
- ITER control-box concept

Achievements:
- Control-box prototype running at ESS
- Naming convention with tools implemented
- Well-defined safety/protection system architecture
- Parameter-list tools implemented
- Interfaces with instrument controls defined
- “BLED” database for linac configuration

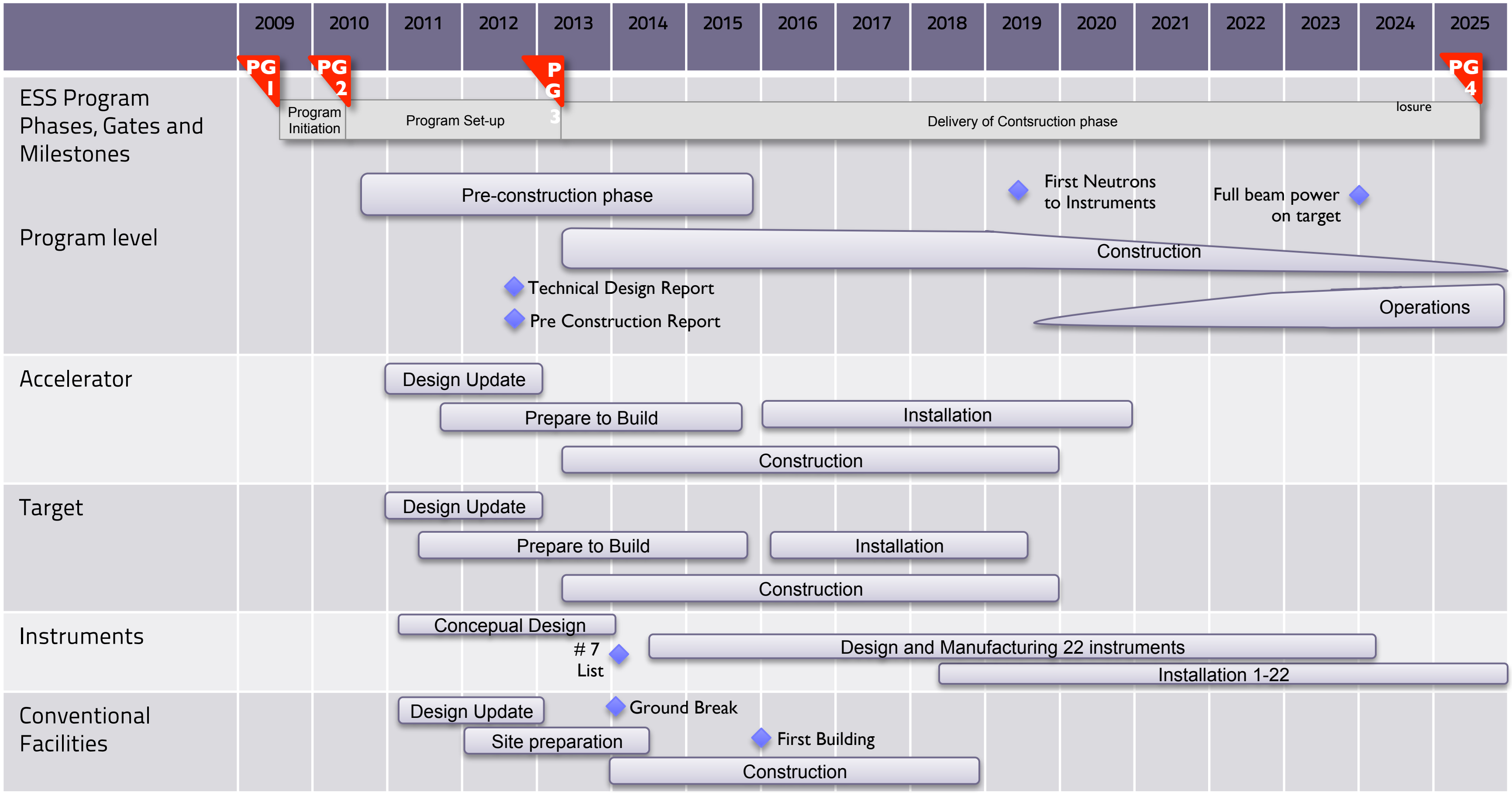
E. Laface, THPPP047



Prototype available

Working prototype in 2012

ESS Master Programme Schedule



A Green Field Today…

Neutrons in 2019!