EUROPEAN SPALLATION SOURCE

TECHNICAL PLANNING FOR THE OPERATIONAL PHASE

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THE ESS

Key Linac parameters

Energy	2.0 GeV
Current	62.5 mA
Repetition rate	14 Hz
Pulse length	2.86 ms
Losses	<1W/m
Ions	p

Controls

Control variables.	~1.6E6 PVs
MPS and PSS	
EPICS7	
µTCA.4	

Flexible/Upgradable design

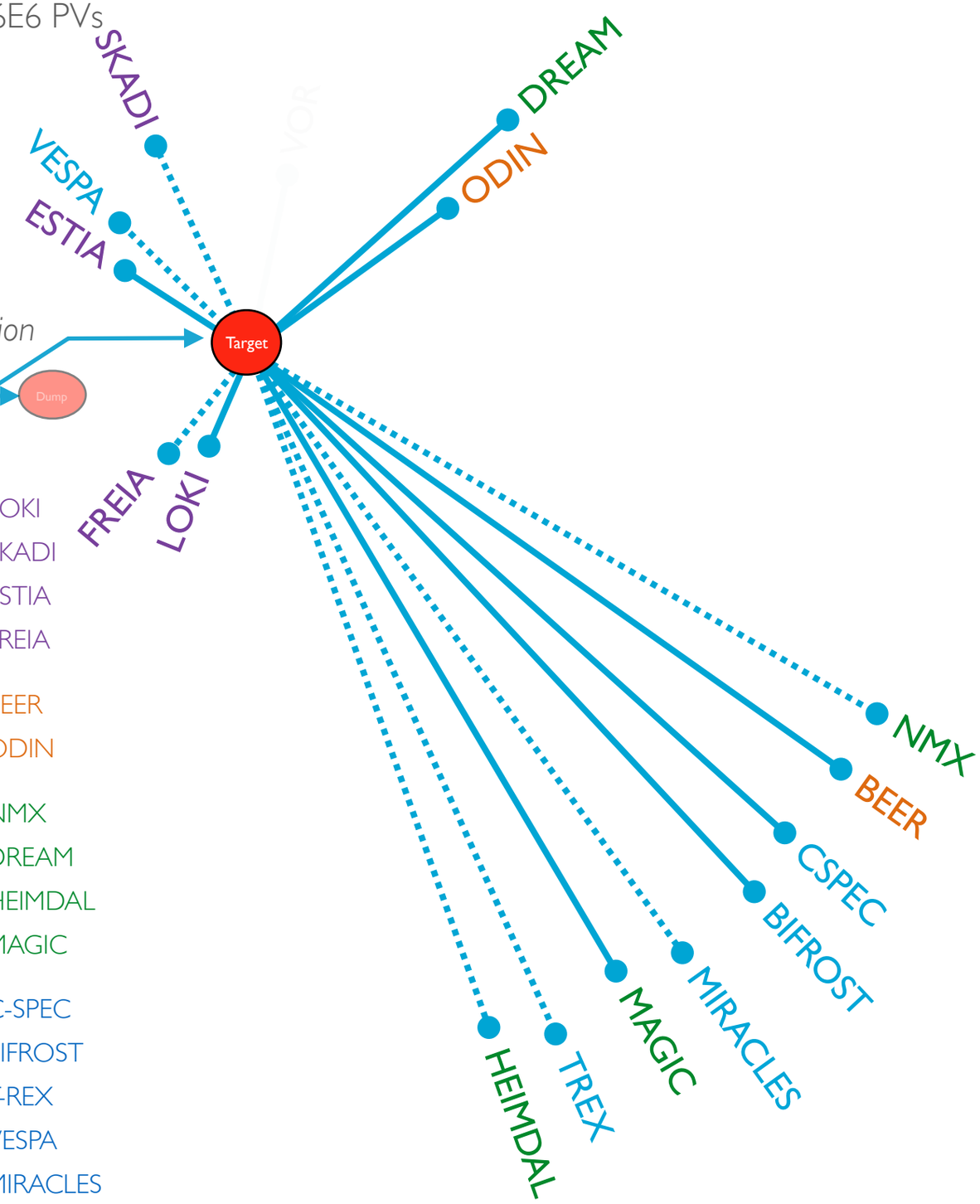
Minimize energy consumption

Rotating tungsten target

Target diameter	2.6 (0.45) m
Mass	11 (3) tons
	36 sectors
Rev. freq.	~0.4 Hz
Expected lifetime	5 years
Cooling	He gas
Beam ports	42
Peak flux	~30-100 x ILL
Cold moderator	Liquid H_2
	7 K
	30 mm
Thermal moderator	H_2O
	300 K
	30 mm

Instruments

Large Scale Structures	LOKI
	SKADI
	ESTIA
	FREIA
Engineering	BEER
	ODIN
Diffraction	NMX
	DREAM
	HEIMDAL
	MAGIC
Spectroscopy	C-SPEC
	BIFROST
	T-REX
	VESPA
	MIRACLES



LINAC NEEDS I

- Obsolescence:
  - Readout electronics systems need to be upgraded on about a 10 year cycle due to obsolescence of components

- Radiation damage:
  - Component replacements at regular intervals due to limited lifetime in radiation environment

- Cryogenics
  - Helium and nitrogen
  - Other consumable

- Vacuum
  - Spares: pumps, gauges, RGA, valves, clean rooms, leak detectors, control system, controllers, gas injection and venting systems.
  - Supplies: detergents, chemicals, laboratory tools, hardware, Al foils, wipes, paper, gaskets, o-rings, bolts, shop supplies, oil, grease, external services, etc

LINAC NEEDS II

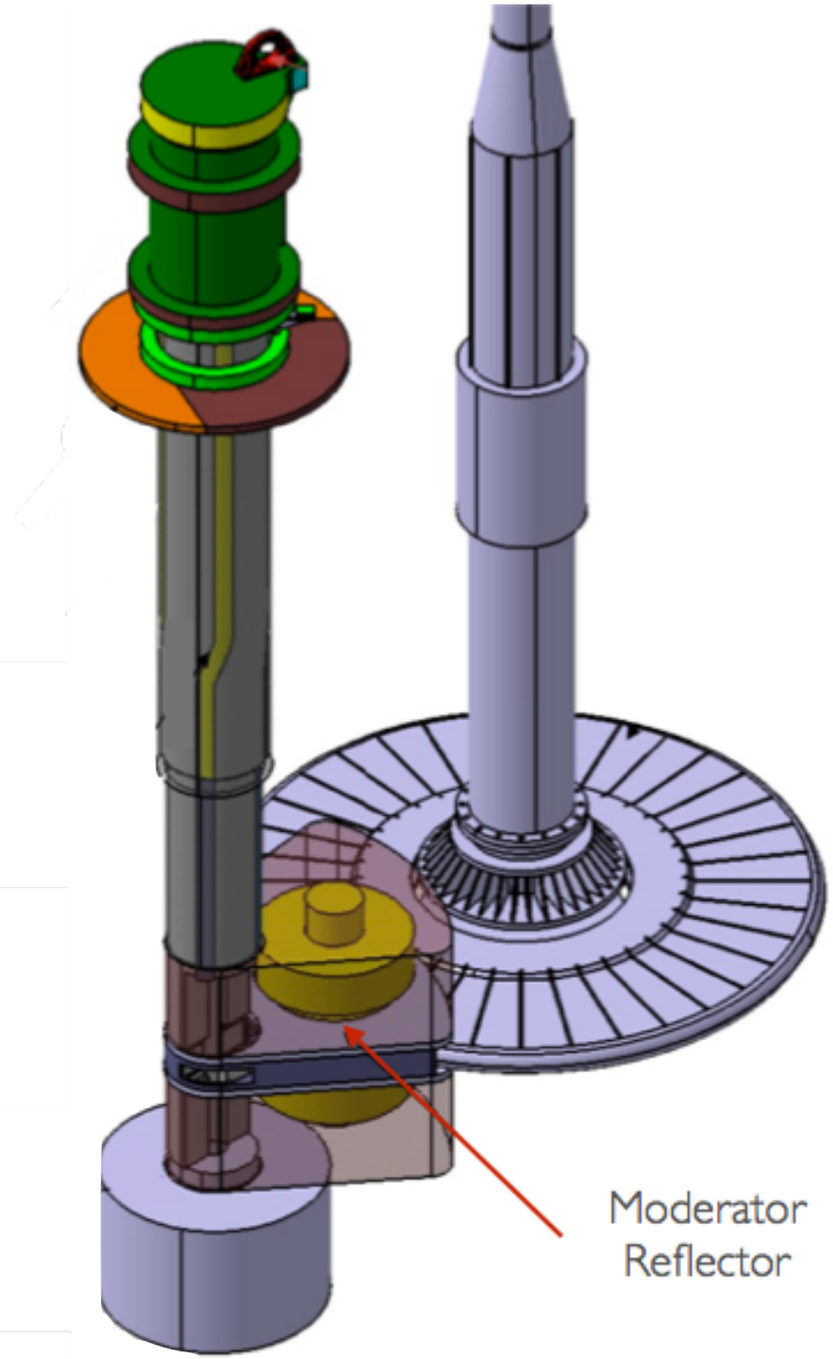
- Lifetime
  - Klystrons have a lifetime of ~60k hours and tetrodes ~20k hours
- Modulators
  - Spare parts for the modulators
  - Spare magnet power converters
  - New oil for replacement (~50’000 liters every 6 years)
- Water cooling
  - Spares, such as hoses, filters, valves, and tools
- Electrical systems
  - Cables, installation material, tools
- Scope recovery
  - Beam instrumentation
  - RF (klystrons, modulators, more cavities, …)

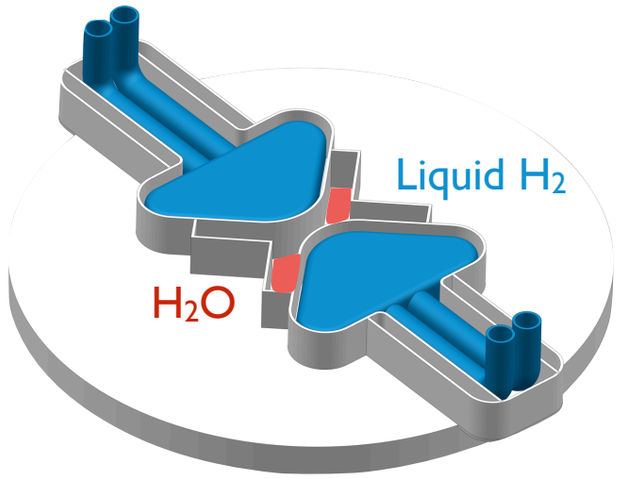
CONTROLS

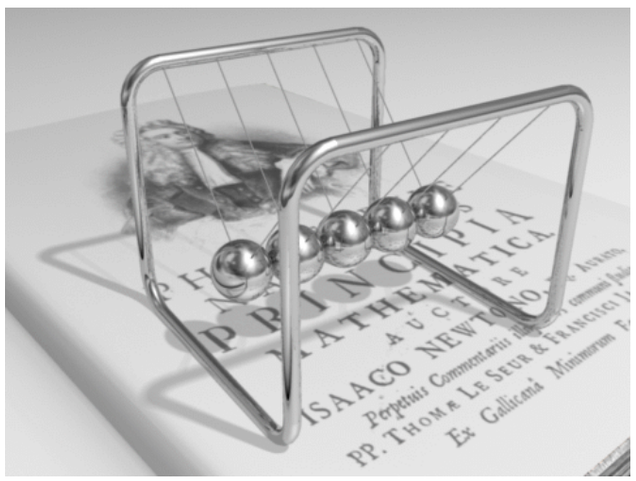
- Spare parts
  - µTCA
  - Power supply
  - Carrier Hub (MCH)
- Infrastructure
  - Network switches,
  - Network equipment,
  - Industrial PCs,
  - Data storage and computer facilities

Target wheel and Moderator/Reflector

- Target wheel has a lifetime of 5 year at full power
- Moderator reflector plug has a lifetime of 1 year at full power

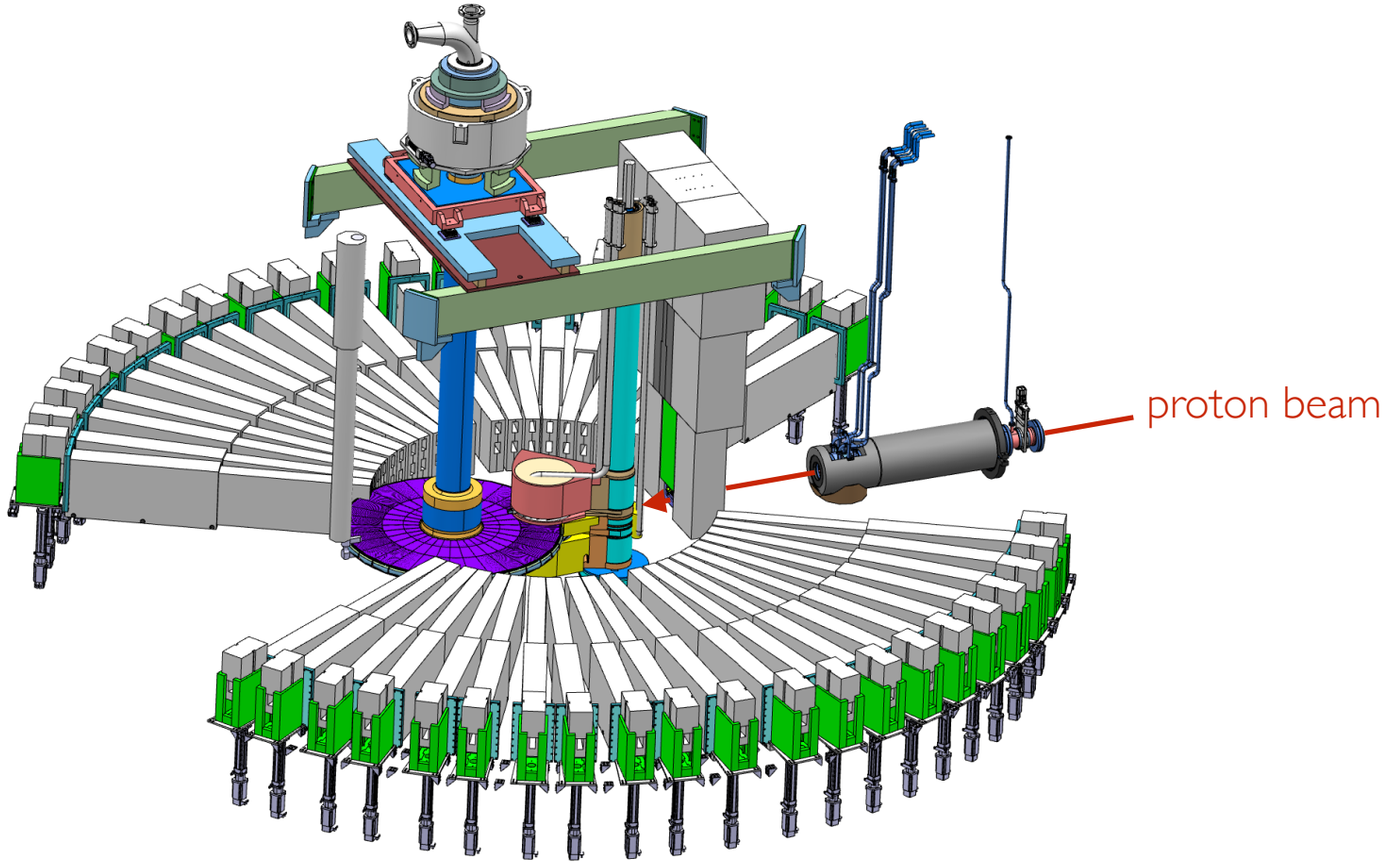






Proton Beam Window and Neutron ports

- Proton beam window has a lifetime of 6 months at full power
- There are 42 neutron ports in the target, 15+1 will be connected to instruments in the construction budget



Courtesy: Sara Ghatnekar and Daniel Lyngh

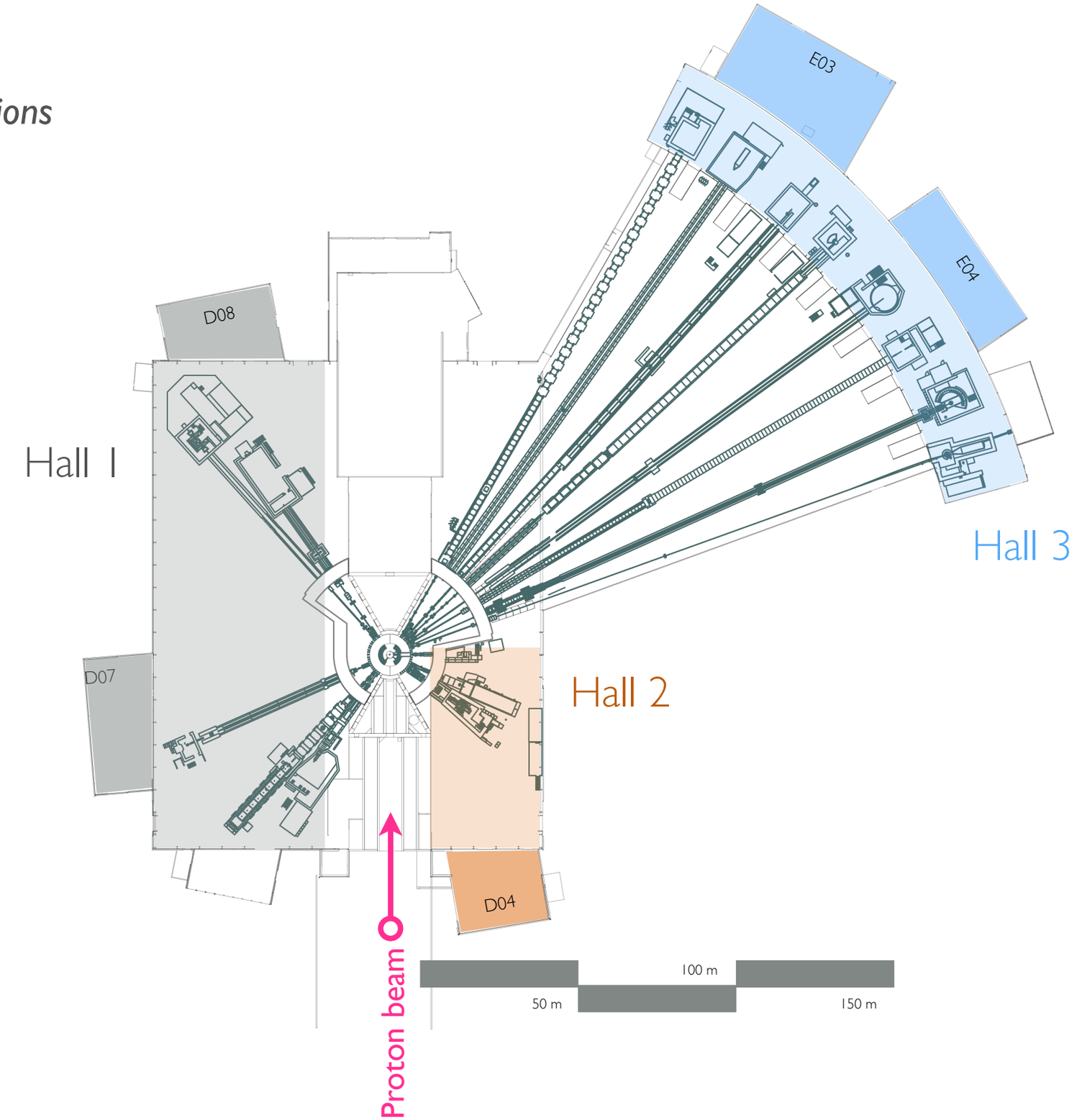
INSTRUMENTS

Large scale structures	**LOKI**	Broadband SANS	UK	
	SKADI	General purpose SANS	DE FR	
	ESTIA	Focusing reflectometer	CH	
	FREIA	Liquids reflectometer	UK	
Engineering	**BEER**	Engineering diffractometer	DE CZ	
	ODIN	Multi-purpose imaging	ESS DE CH	
Diffraction	NMX	Macromolecular crystallography	ESS HU FR NO	
	DREAM	Powder diffractometer (bispectral)	DE FR	
	HEIMDAL	Hybrid diffractometer	DK CH NO	
	MAGIC	Magnetism single-crystal diffractometer	FR DE CH	
Spectroscopy	**C-SPEC**	Cold chopper spectrometer	DE FR	
	BIFROST	Extreme-environments spectrometer	DK CH HU NO FR	
	T-REX	Bispectral chopper spectrometer	DE IT	
	VESPA	Vibrational spectroscopy	IT UK	
	MIRACLES	Backscattering spectrometer	ESS FR HU ES	

- Life sciences
- Soft condensed matter
- Energy research
- Archeology and heritage conservation
- Chemistry of materials
- Magnetism and superconductivity
- Engineering and geo-sciences

INSTRUMENTS

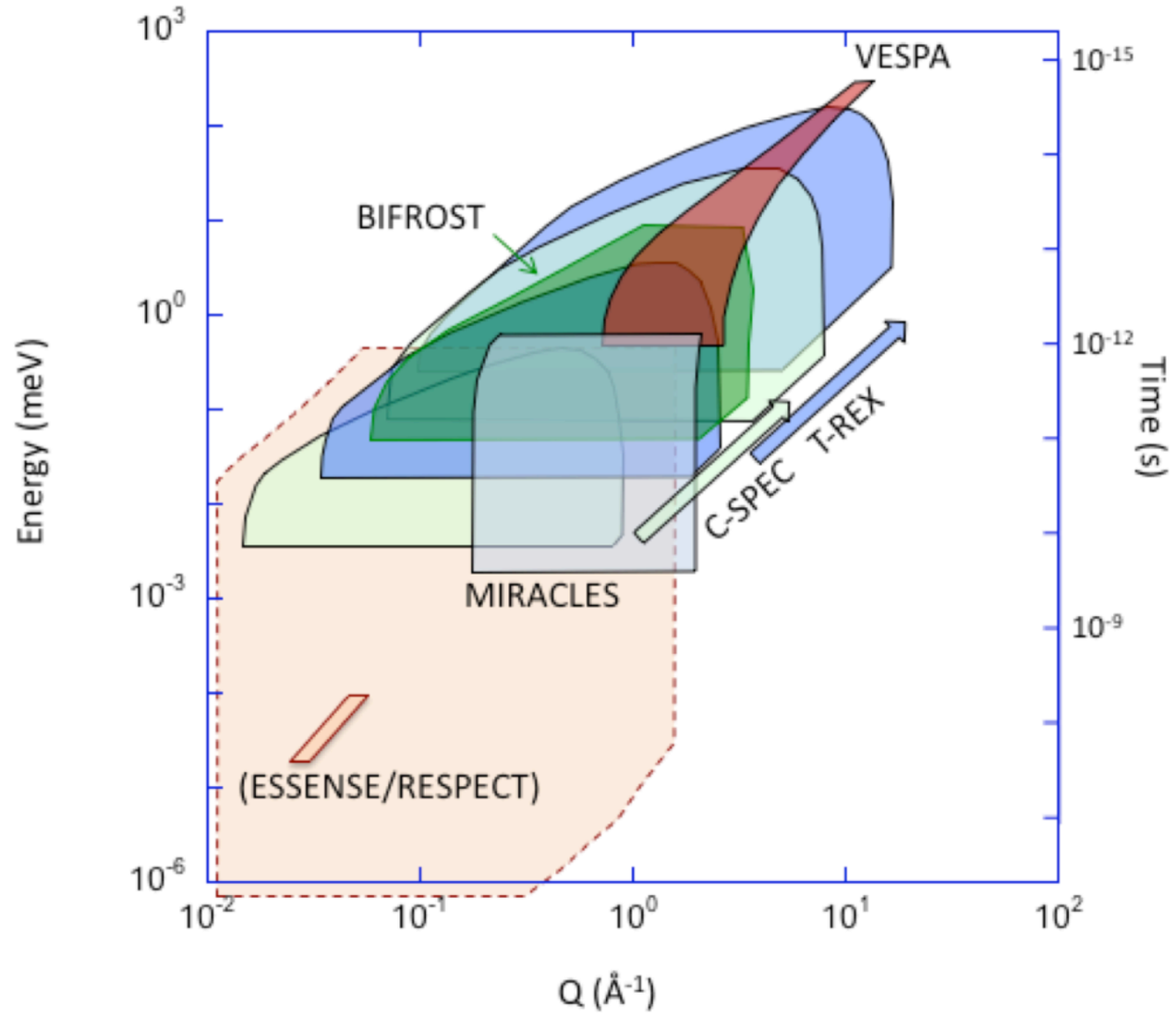
- Hall 1:
  - *D07: Deferred to early initial operations*
    - *1 x life science*
    - *1 x cold room*
  - D08:
    - 1 x chemistry
    - 1 x radioactive material lab
- Hall 2:
  - D04:
    - 1 x life science
    - 1 x cold room
    - 2 x instrument room
- Hall 3:
  - E03:
    - 1 x engineering
  - E04
    - 1 x life science
    - 1 x cold room
    - 1 x instrument room
    - 1 x chemistry
    - 1 x characterization



GAP ANALYSIS

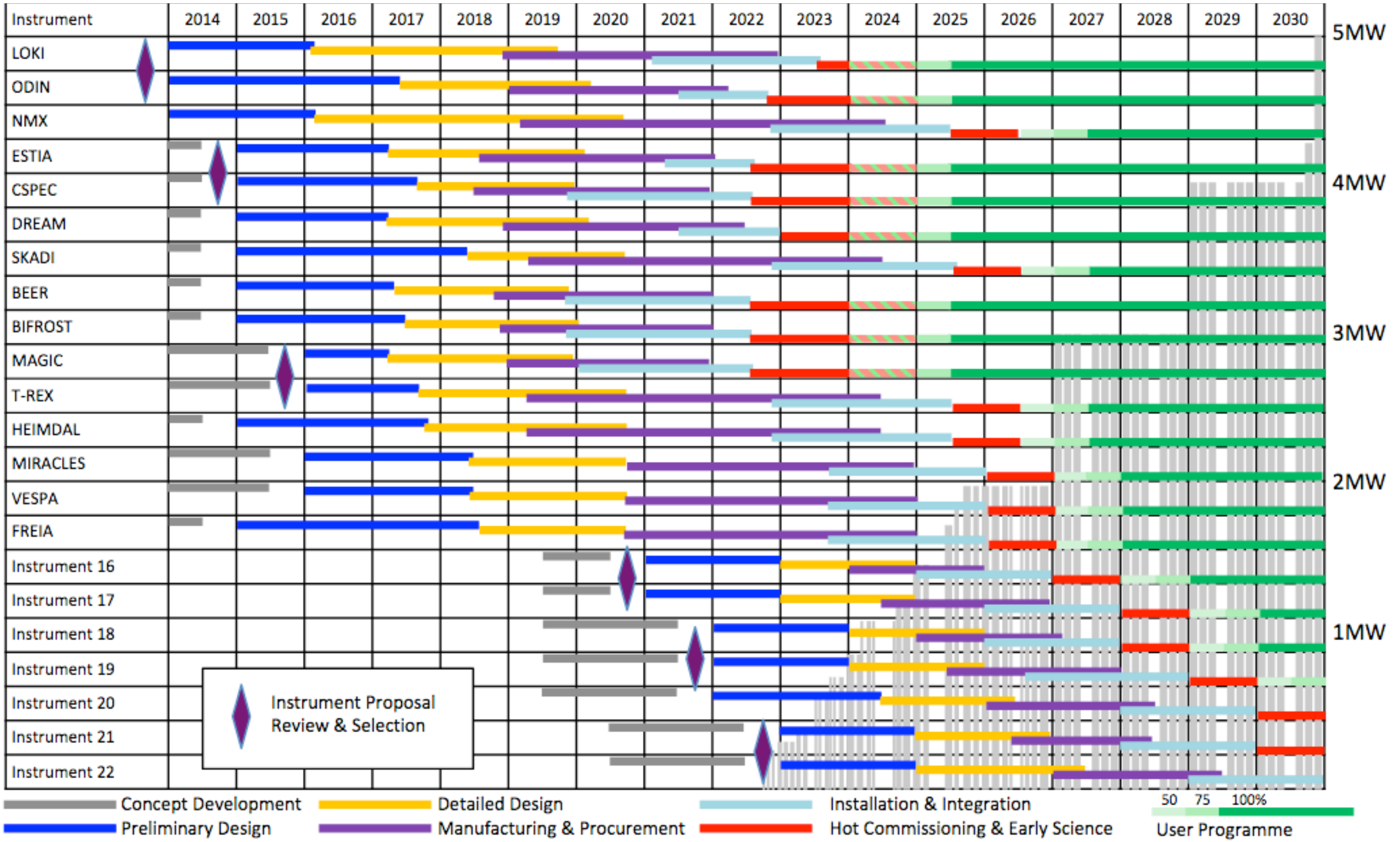
- Guide choice of instruments 16-22
  - Requested by SAC

1. High-Priority Capability Gaps
   - Particle Physics
   - High-Resolution Spin-Echo
2. Other Significant Capability Gaps
   - High Pressure Diffraction
   - Grazing-Incidence SANS
   - Very Fast Spectroscopy
   - Wide-Bandwidth Spectroscopy
   - High Magnetic Fields
3. Lower-Priority Capability Gaps
   - Bio-SANS
   - Hydrogenous-Sample Diffraction
   - Wide-Angle Spin-Echo



Courtesy: Ken Andersen

Tentative Instrument ramp-up



Courtesy: Ken Andersen. *Version 4/10/2018, based on Instrument Construction Working Schedule V4.0*

Potential Instruments for particle physics

- ANNI
  - ANNI is a cold neutron beam facility for particle physics, it will make full use of the ESS pulse structure
- HI-Beam
  - Its scientific program includes search for mirror neutrons, measurements of weak nucleaon-nucleaon interactions and search for n-nbar oscillation
- UCN Source
  - Ultra-cold neutrons (UCN) play an important role to address key questions of particle physics at the low-energy, high-precision frontier, complementary to experiments done at high-energy particle accelerators.
- NNBAR
  - A sensitive search for neutron-antineutron oscillations can provide a unique probe of some of the central questions in particle physics and cosmology.

- Status of the Instruments
  - Today, all three instruments and HIBEAM are pushed by specific consortia.
  - For ANNI, a design is available and a full ESS instrument proposal was submitted jointly by scientists from different universities and labs.
  - For UCN Source and NNBAR detailed designs are not yet finalised, but letters of intent (LoI) with preliminary gain factors were submitted.
  - A Scientific and Technical Advisory Panel (STAP) for fundamental physics has been established to advise and later to review the instrument proposals and letters of intent.

https://europeanspallationsource.se/science-using-neutrons/particle-physics

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"Whoever has visions should go to the doctor"

Helmut Schmidt

EUROPEAN SPALLATION SOURCE

"Whoever has visions should go to the doctor"

Helmut Schmidt

"Helmut Schmidt – a German leader with a global vision"

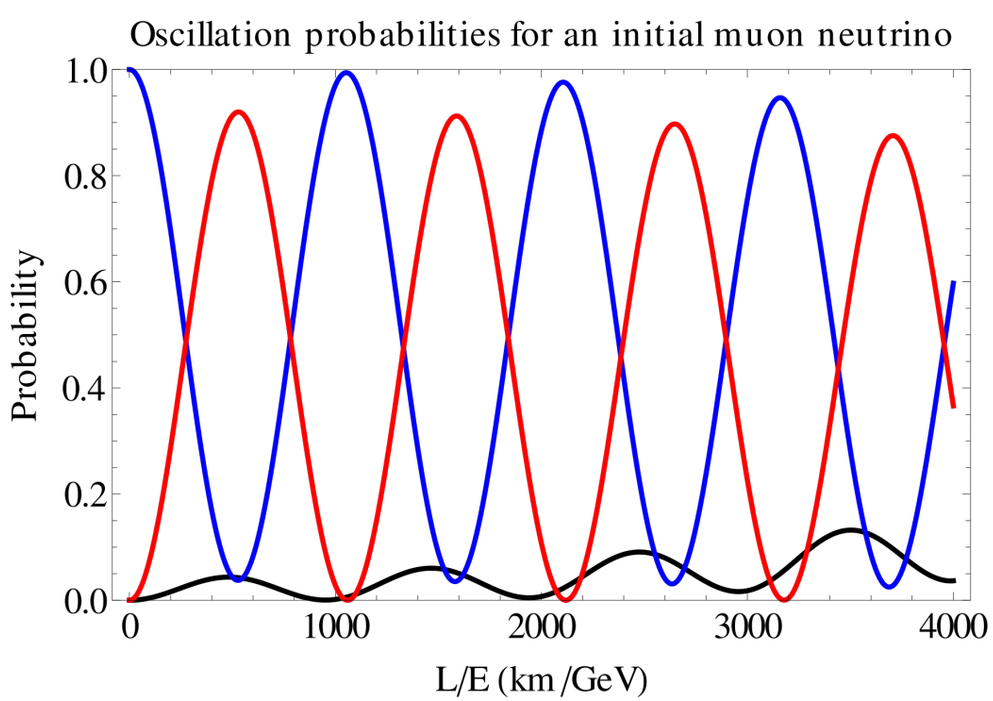
The Guardian

. . . sometime in the future

LUND TO GARPENBERG

ESSnuSB has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 777419

CHAMELEONS OF PARTICLE PHYSICS



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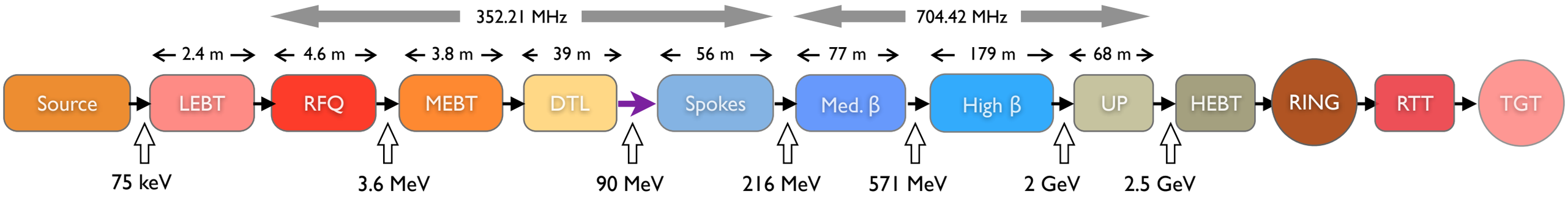
Top Level Parameters



Key Linac parameters:

Energy	2.5 GeV
Current	50 + ~60 mA
Repetition rate	14 + 14 Hz
Pulse length	2.86 + 2.86 ms
Losses	<1W/m
Ions	p and H-

Key Ring parameters:

Energy	2.5 GeV
Np/fill	2.8E14
Repetition rate	4x14 Hz
Circumference	~384 m
Losses	<1W/m
Injection	Laser stripping

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Required Changes in the Linac

	IS+LEBT	RFQ	MEBT	DTL	Spoke	Medium beta	High beta	High beta+
New device	New	~New	~New	—	—	—	—	New
Cooling	—	Additional	Additional	Additional	Additional	Additional	Additional	
Tunnel	Device capacity / pipes / temperature				Cryo-line/Cryomodule/Coupler/Waveguide			
Gallery	Cooling skids / Klystron cooling / pipes				Klystron cooling / pipes / skids?			New
RF	—	Additional	Additional	Additional	Additional	Additional	Additional	
		Klystron	Amplifier	Klystron	Tubes / LLRF			Klystron
		Modulator	PC	Modulator	Modulator / Power converters			Modulator
Cryo	—	—	—	—	Additional	Additional	Additional	
					Cryoline / Cryo plant			
Magnets	Partially	—	Partially	—	Corrector			

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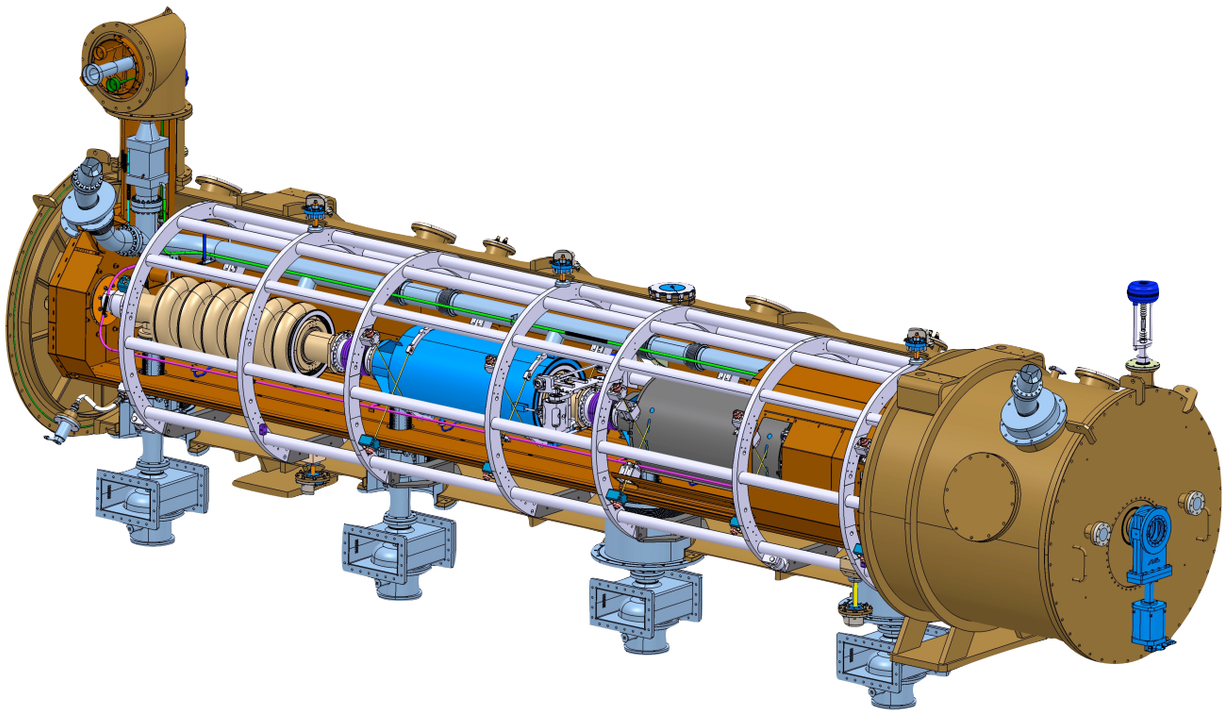
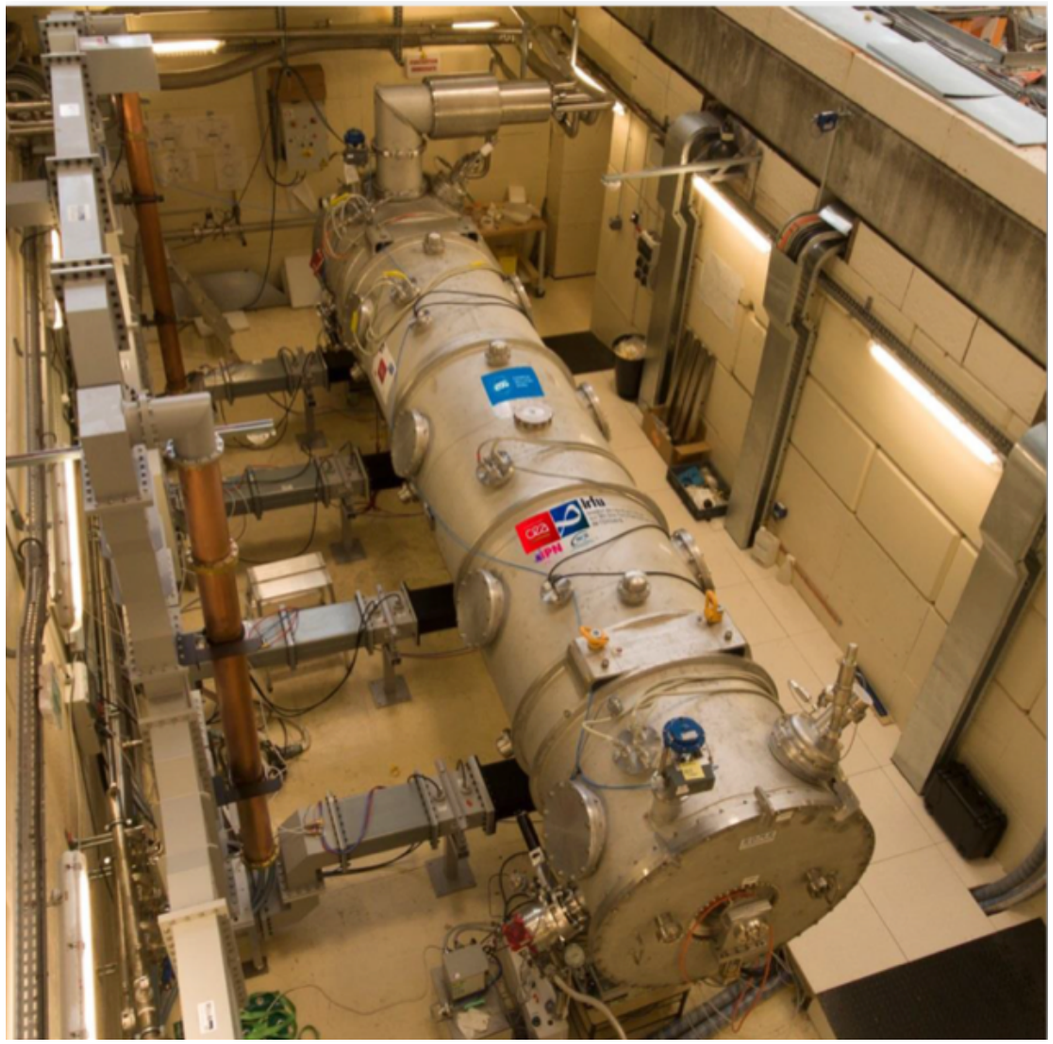
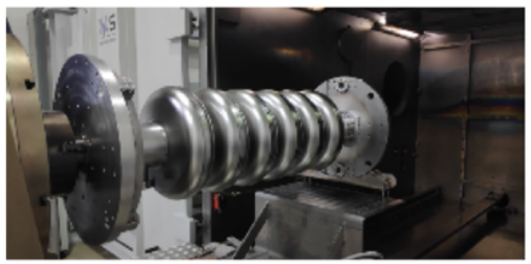
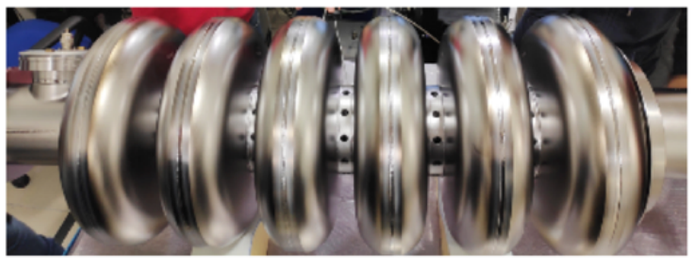
ESS Elliptical Cryomodule









9 × Mβ

21 × Hβ

8 × hβ

CRYOGENICS

Major RF Pieces

- Klystrons and modulators should be upgraded to cope with twice the average power

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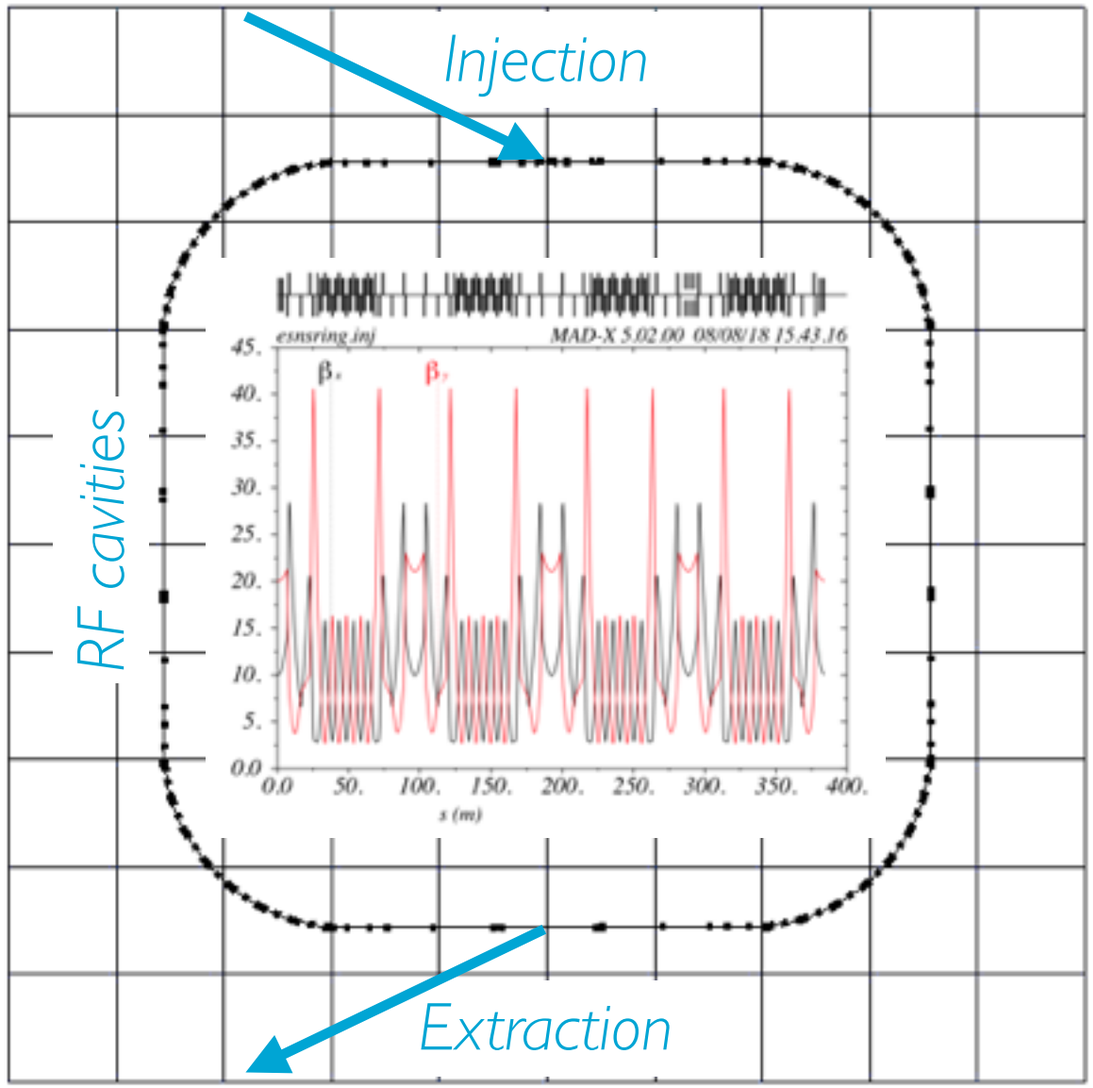
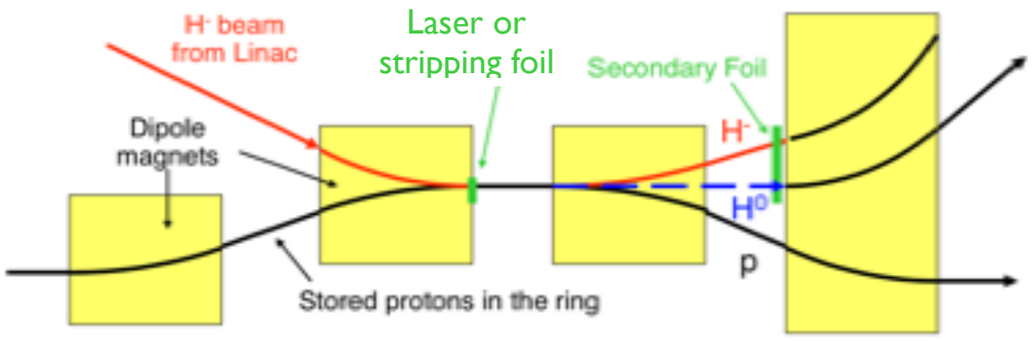
Accumulator Ring

- Adjustable permanent magnets for bending
  - Lower energy consumption
- Collimators
  - Reducing uncontrolled losses
- RF cavities and power supplies
  - Keeping the extraction gap clean
  - SSAs as RF sources
- Kicker magnets for extraction
- Shielding





Courtesy: Ye Zou, Horst Schönauer

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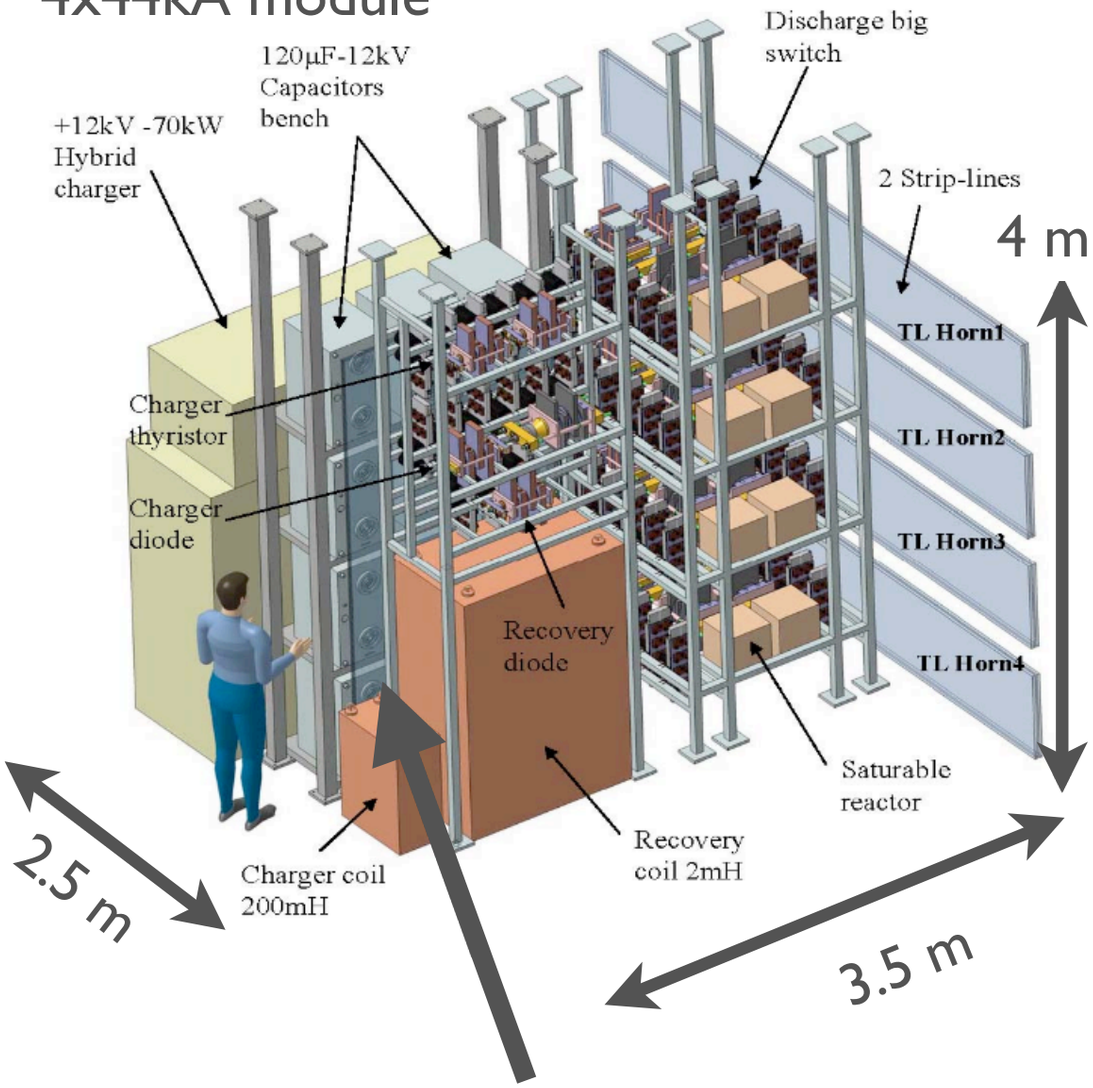
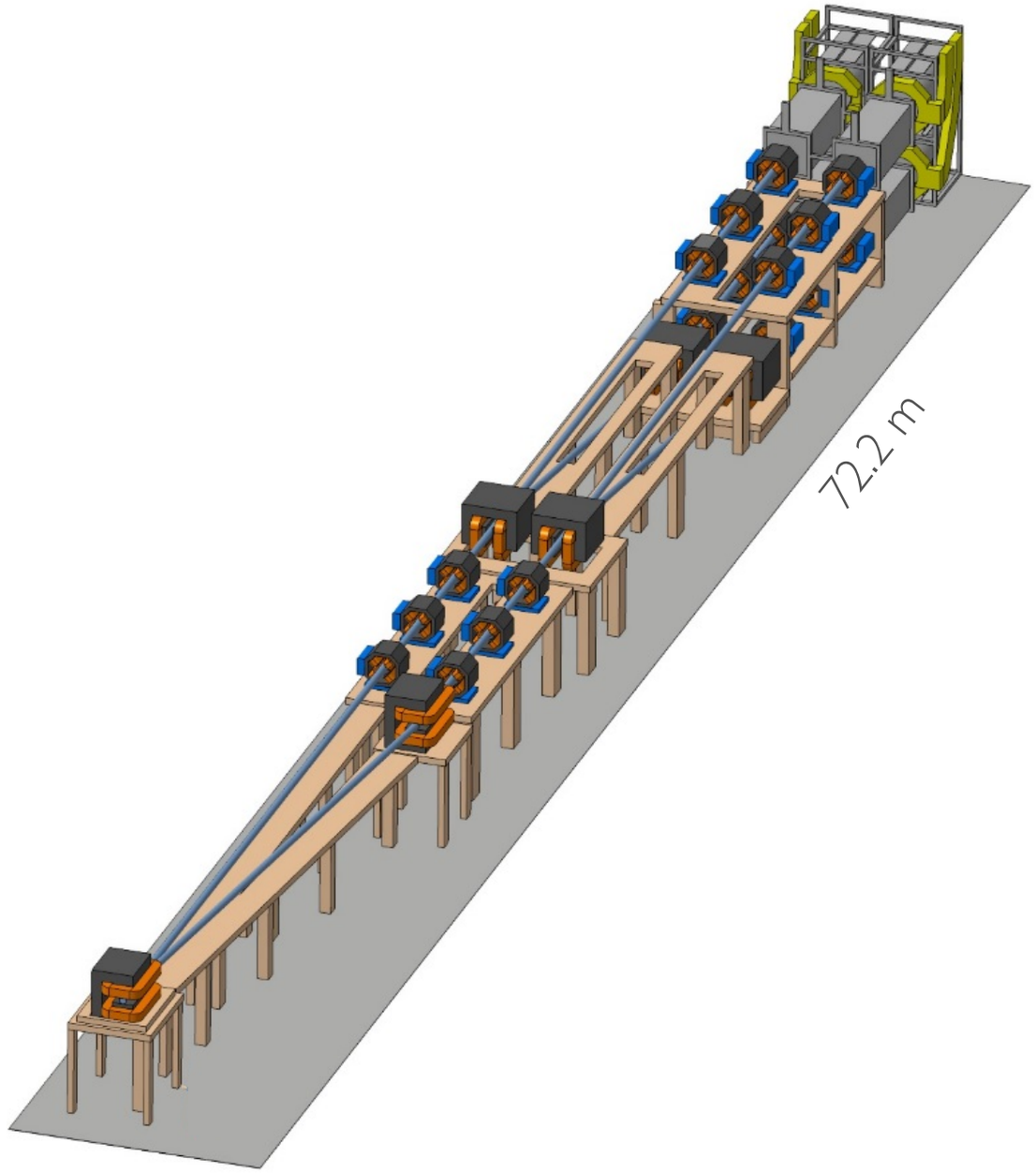
Target and Horn

4x44kA module



Large strip-lines



Courtesy: Elian Bouquerel and Pascal Poussot

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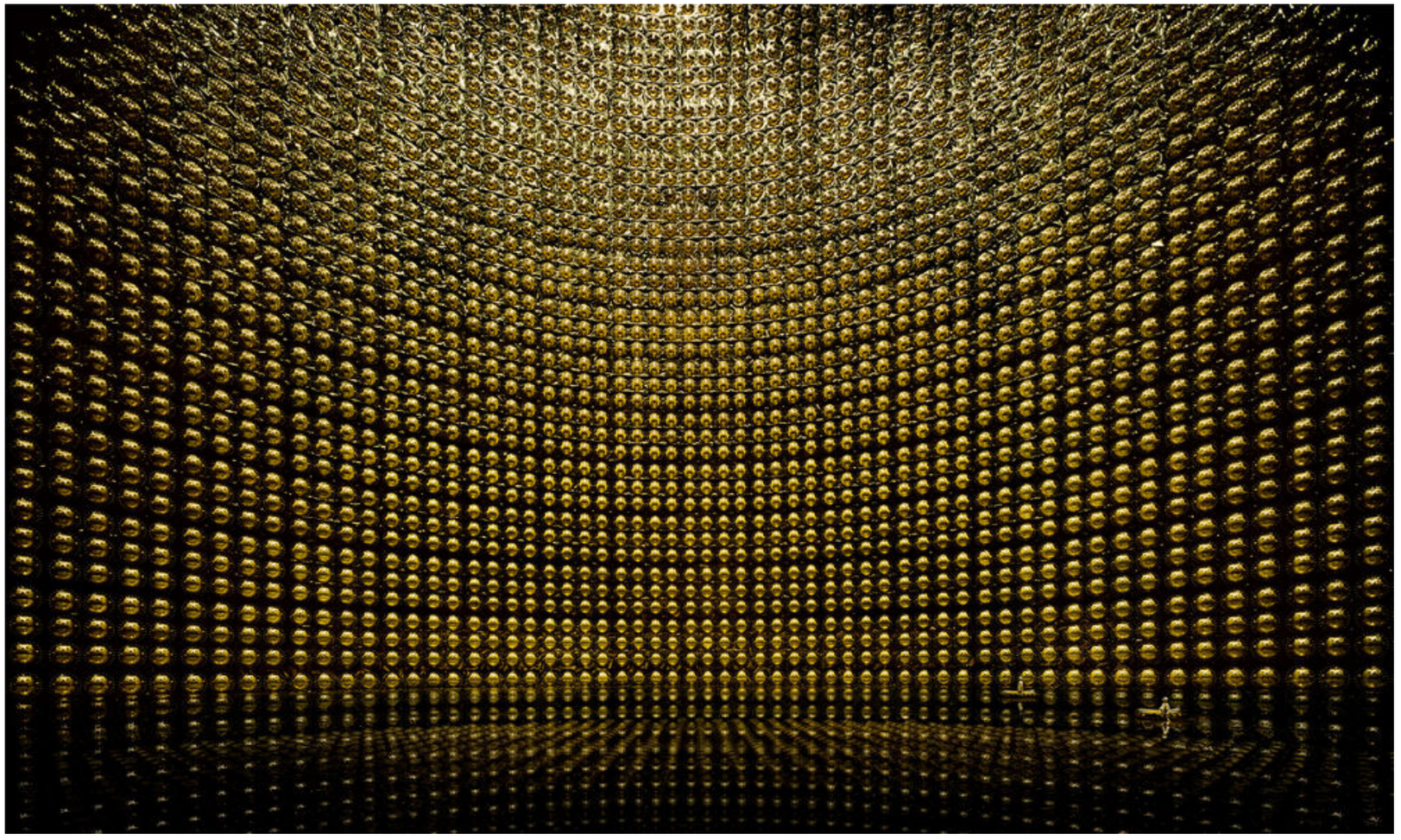
DETECTORS

- 1 Megaton of ultra pure water as the far detector
  - That is 20 times the volume of the super-Kamiokande
- 1000 meter deep underground
  - To decrease the noise and background from cosmic radiation



Super-Kamiokande Detector

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