UPPSALA UNIVERSITET

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ESS-Based Long-baseline Neutrino Project ESSnuSB

- Linac upgrade, accumulator ring, and target station

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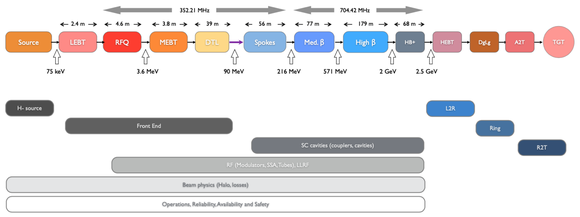
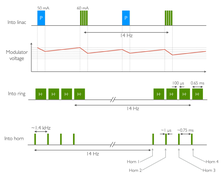
According to the baseline design of the 5 MW accelerator under construction in Lund, Sweden, its duty cycle will be only 4%, which leaves room for increasing the beam power and duty cycle to 10 MW and 8%, respectively. The linac power upgrade will be realized by increasing the linac pulse frequency from 14 to 28 Hz. The ESS linac pulse is 3 ms long which is too long for the cosmic ray-related background in the far neutrino detector and a 400 m circumference accumulator ring will be used to compress the beam pulse to 1.3 us. In order to be able to handle the high proton beam power, the target station will comprise four separate granular targets with neutrino horns and a decay tunnel.

Linac upgrade

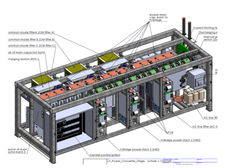
Key parameters	ESS beam	ESSnuSB beam
Average power	5 MW	5 MW
Energy	2.0 GeV	2.5 GeV
Current	62.5 mA	62 mA
Repetition rate	14 Hz	14 Hz (×4)
Pulse length	2.86 ms	<3.5 ms
Losses	<1 W/m	<1 W/m
Ions	Proton	H-



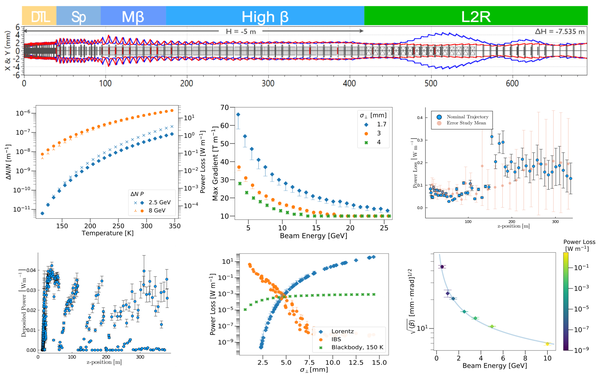
Pulsing in the linac, ring, and target



Modulator upgrade



H- transport and losses



arXiv:2103.16195 [physics.acc-ph]

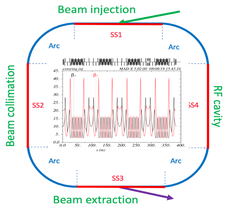
Accumulator ring

Main challenges

- Beam loss control due to high beam power
- Space-charge tune shift due to high beam intensity
- Instabilities (e-p instability)

Main parameters

- Ring circumference: ~ 400 m
- Injection turns: ~ 600
- Extraction gap: ~100 ns
- Total beam loss (1 W/m): $<10^{-4}$
- Collimation efficiency: >90%
- Space-charge tune shift: <0.1

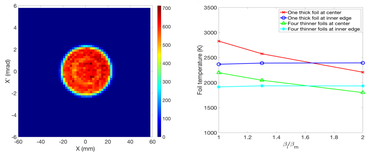


Lattice design

- Developed by Horst Schönauer at CERN
- Circumference: 384 m
- 4-fold symmetry
- 4 straight sections (SS1~SS4) and 4 arc sections (Arc)
- Fixed injection chicane and fast programmable bump for injection painting

Beam injection

- Foil stripping and injection painting
- Stacked thin foils and mismatch injection to minimize foil temperature

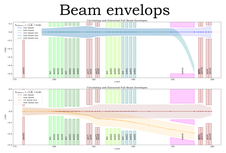


- Painting to quasi-uniform beam, with 100% emittance of 60 π mm mrad in both planes
- Very small tune spread (~0.05)
- Foil temperature under 2000 K

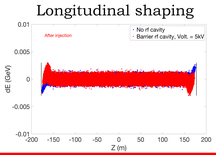
Beam extraction and RF

- Single-turn extraction system
  - Vertical kicker and horizontal septum
- RF cavity to keep the extraction gap clean

Beam envelops



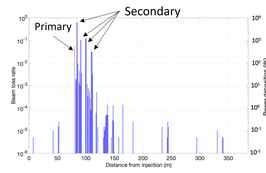
Longitudinal shaping



Beam collimation

- Two stage collimation system
- Optimal phase advances to maximize interception efficiency

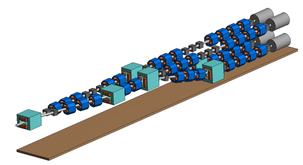
Beam loss map



- Collimation Efficiency: ~ 97 %

Switchyard

- Switch and deliver beam pulses to the 4 horns



Target station

Hot Cell

- Able to manipulate/repair hadron collector
- Work under radioactive environment.

Power Supply Unit

- 16 modules (350 kA pulse/14 Hz)
- Located above the beam switchyard
- Outside of the radioactive part of the facility
- Good position to synchronize with switchyard PSU

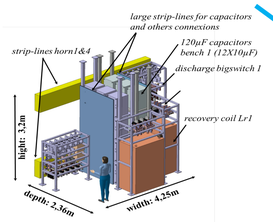
Packed Bed Target

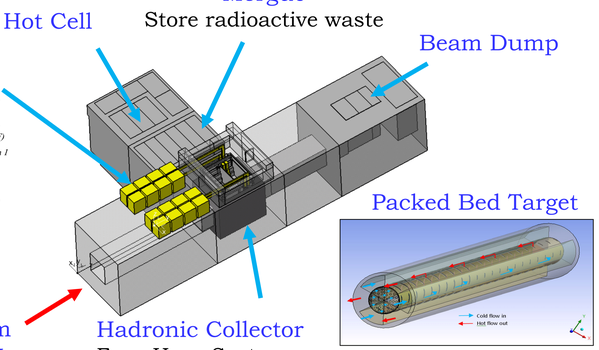
- Power 1.25 – 1.6 MW
- Potential heat removal rates at the hundreds of kW level
- Helium cooling (10 bars)
- Separated from the horn

Focusing system

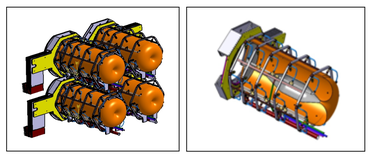
- 4-horn/target system to accommodate the MW power scale
- Solid target integrated into the inner conductor : very good physics results but high energy deposition and stresses on the conductors
- Best compromise between physics and reliability

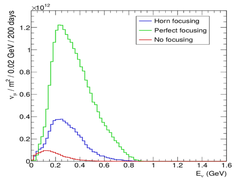
Power Supply Unit





Packed Bed Target





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