Overview of the ESSnuSB accumulator ring

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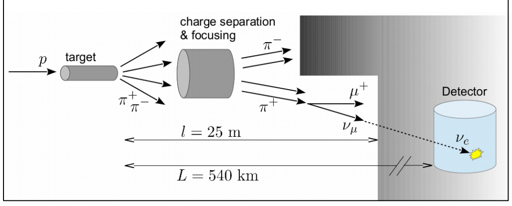
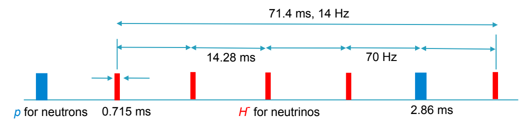
Abstract

The European Spallation Source (ESS) is a research center based on the world's most powerful proton driver, 2.0 GeV, 5 MW on target, currently under construction in Lund. With an increased pulse frequency, the ESS linac could deliver additional beam pulses to a neutrino target, thus giving an excellent opportunity to produce a high-performance ESS neutrino Super-Beam (ESSnuSB). The focusing system surrounding the neutrino target requires short proton pulses. An accumulator ring and acceleration of an H⁻ beam in the linac for charge-exchange injection into the accumulator could provide such short pulses. In this paper we present an overview of the work with optimizing the accumulator design and the challenges of injecting and storing 1.1·10^{15} protons per pulse from the linac. In particular, particle tracking simulations with space charge will be described.

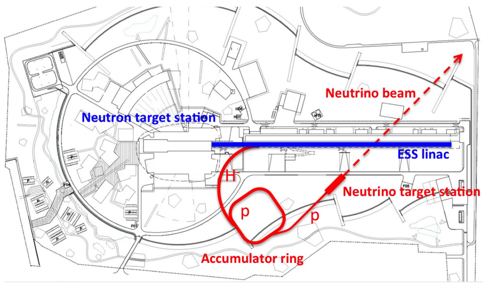
ESSnuSB experiment layout



Linac pulsing scheme



ESSnuSB at the ESS site



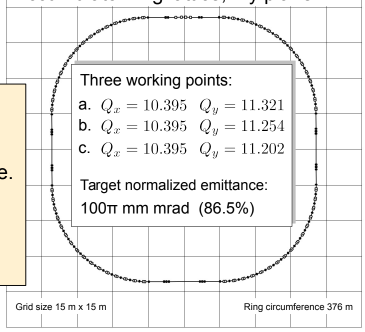
Parameters	ESS nominal	ESSnuSB baseline
Beam particle, linac	p	H⁻
Beam power	5 MW	5 MW
Pulse length	2.86 ms	0.715 ms
Linac rep. rate	14 Hz	70 Hz
Pulse intensity	1.1·10^{15}	2.75·10^{14}

Two simulation campaigns

.... in pyORBIT to evaluate the accumulator ring design and the injection painting procedure.

1) Worst-case scenario: track at full accumulated intensity
2) Include injection painting

Accumulator ring lattice, x-y plane



Three working points:

a. $Q_x = 10.395$ $Q_y = 11.321$
b. $Q_x = 10.395$ $Q_y = 11.254$
c. $Q_x = 10.395$ $Q_y = 11.202$

Target normalized emittance: 100π mm mrad (86.5%)

1) Full intensity

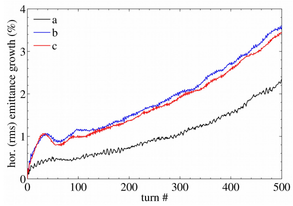
- After complete injection, 2.75E14 protons in the ring.
- Pretend injection already complete, track final beam for 500 turns
- Look at emittance growth and tune spread.
- Compare the result of three working points a, b and c.
- → Can we fit the beam into one ring?

Simulation parameters

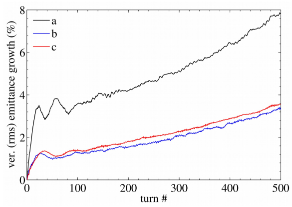
- Gaussian distribution in transverse, matched to lattice.
- RMS geometric emittance 8.5 mm mrad (100 mm mrad norm., 86.5%).
- Gaussian energy distribution, 0.02 % rms spread.
- Uniform distribution in z with 15% gap for extraction.
- 100'000 macro particles
- 128x128x128 space charge bins (2.5D trans. model + 1D long. model)

Selected results

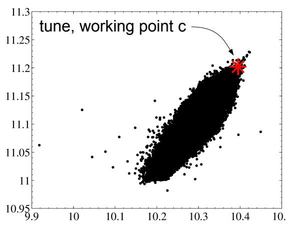
Horizontal emittance evolution

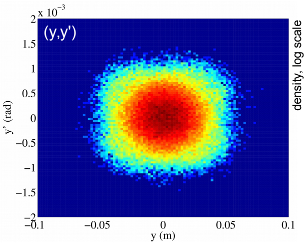


Vertical emittance evolution



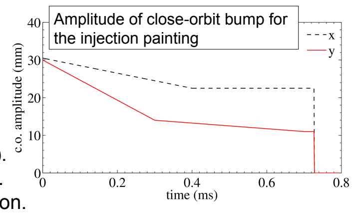
- Tune spread roughly 0.22 for all three working points, consistent with calculations based on the Laslett tune shift.
- Some halo formation, in particular in vertical for working point c.





2) With injection painting

- Simulate the injection process by ramping fast kickers in a variable closed-orbit bump
- Inject one macro-bunch each turn and track. Inject during 550 turns.
- Track for another 50 turns, in total 600 turns.
- Look at emittance growth, profile, tune spread.
- Compare the result of three working points.

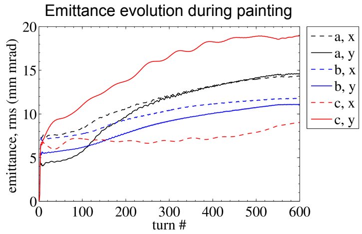


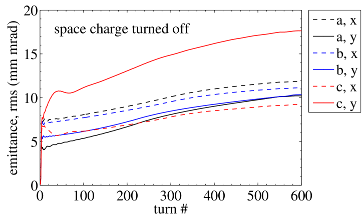
Simulation parameters

- Gaussian distribution in transverse, matched.
- RMS geometric emittance 0.084 mm mrad (linac).
- Gaussian energy distribution, 0.02 % rms spread.
- Uniform distribution in z with 15% gap for extraction.
- 2'000 macro particles per macro-bunch, 1'100'000 mp in final state.
- 128x128x128 space charge bins (2.5D trans. model + 1D long. model)

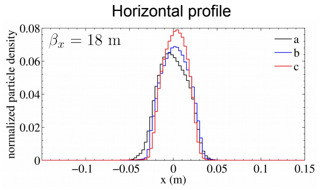
Selected results

Emittance evolution during painting

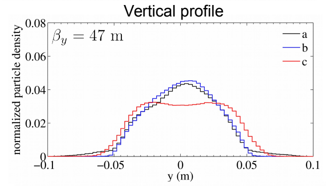


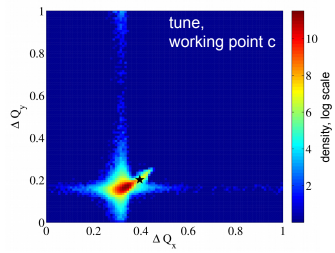


Horizontal profile



Vertical profile





Conclusions and Outlook

- Re-model injection to remove asymmetry and generate more flat profiles.
- Change working point below low-order resonances?

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