ESS neutrino Super Beam plus

Co-funded by the European Union

WP4: LEnuSTORM, Accumulator and Linac

NuFact 2023

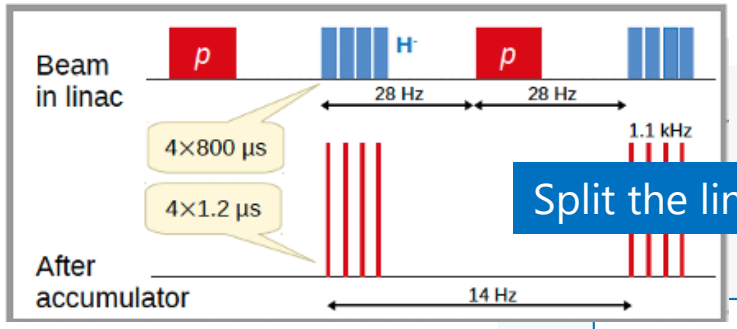
PRESENTED BY NATALIA MILAS ON BEHALF OF WP4

2023-08-20

WP4 objectives

- Design a transfer line from the ESSνSB ring-to-switchyard transfer line to the LEnuSTORM target.
- Design a transfer system from the initial collection and extraction behind the target station up to the injection point.
- Design an injection scheme into the racetrack storage ring.
- To make a conceptual design of a racetrack storage ring for low energy muons produced with a beam from the ESS linac.
- Reassess the design of the ESSνSB accelerator complex in view of LEnuSTORM.

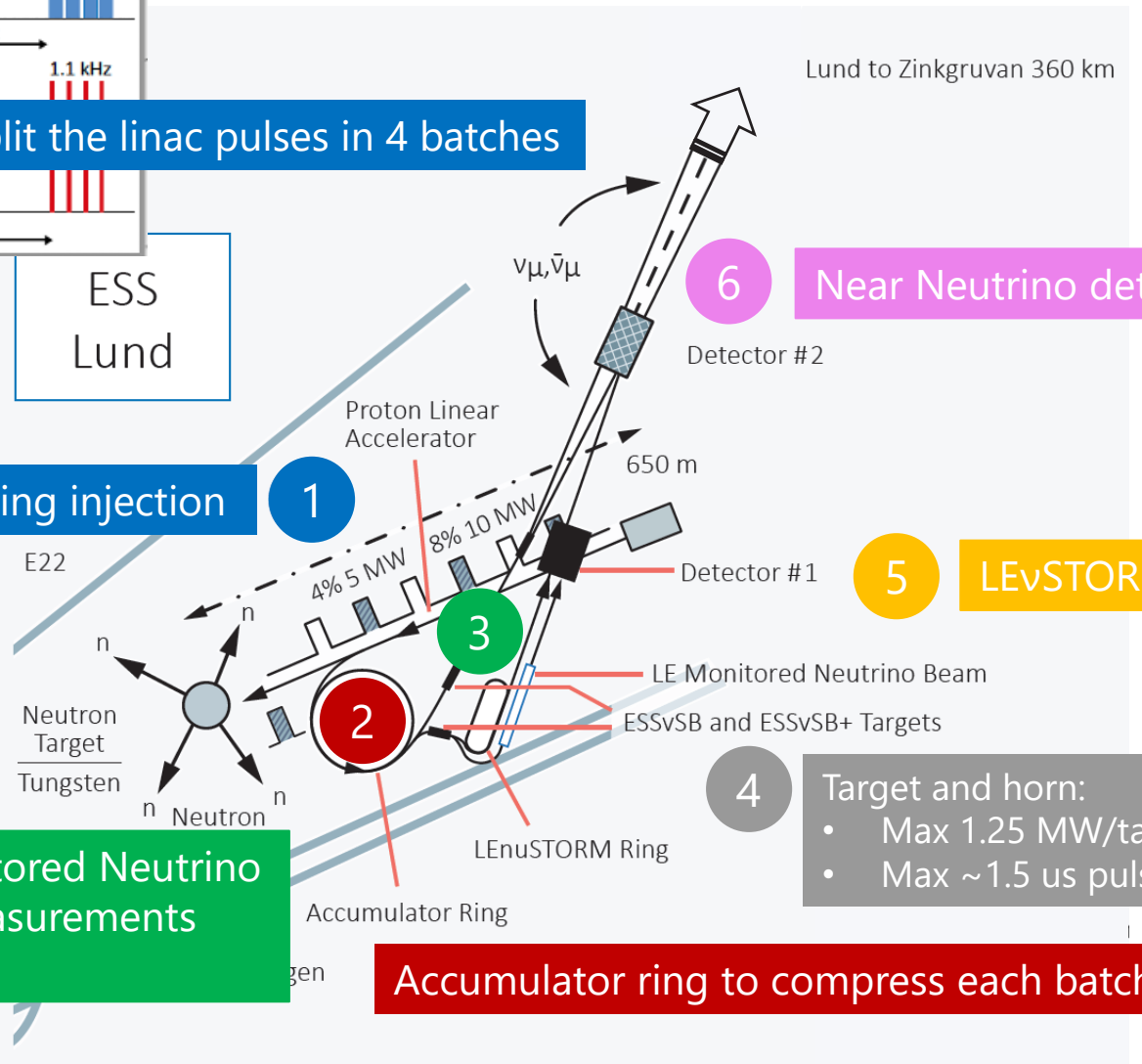
ESSnuSB+ High Level Parameters

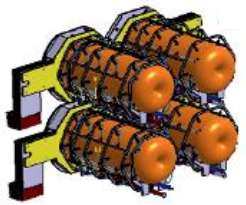


Split the linac pulses in 4 batches

ESS Lund

H- to reduce losses at ring injection 1





Low Energy νSTORM ring and Monitored Neutrino Beam for neutrino cross section measurements and sterile neutrino searches

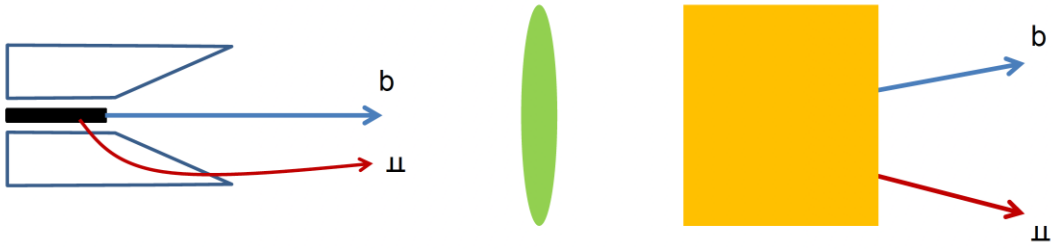
Accumulator ring to compress each batch

WP4 Interfaces

WP3 and WP5

Targets

- Target for neutrino production: we need a common understanding on beam parameters needed (a lot done previously)
- Target for muon production (new)
  - How to filter pions that will be injected into the storage ring?



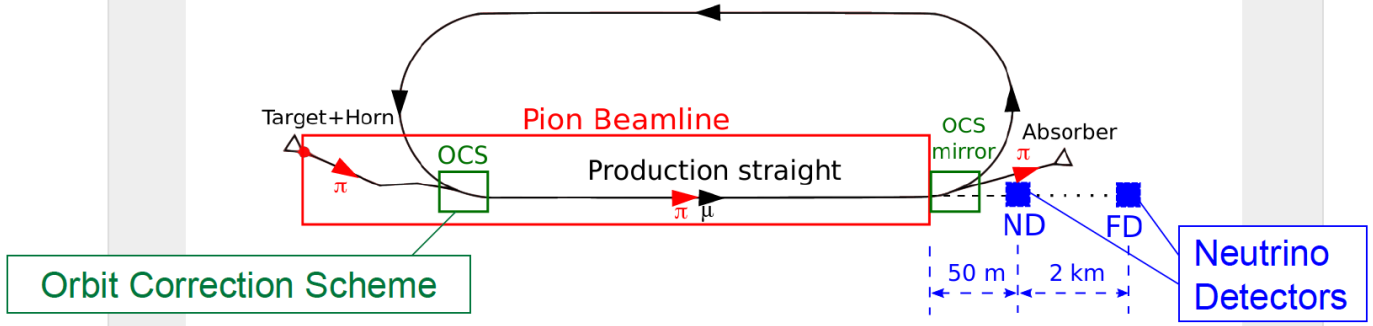
Detectors

- New interface with LEnuSTORM detector
  - Reach desired parameters for the muon beam that can be translated into a neutrino shower, that then will be used for the detector design/simulations

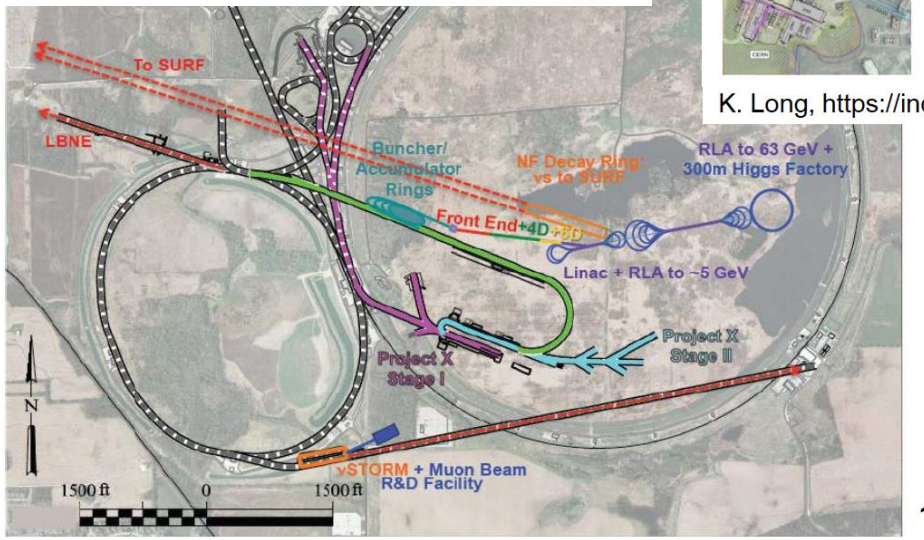
nuSTORM ring design

CERN and FNL rings

nuSTORM racetrack at FNAL:



A. Liu et al., https://iopscience.iop.org/article/10.1088/1748-0221/12/07/P07018



J.-P. Delahaye, https://arxiv.org/abs/1308.0494

120 GeV protons from Main Injector

K. Long, https://indico.cern.ch/event/768000/contributions/3275092/

100 GeV protons from SPS

nuSTORM ring design

Challenges

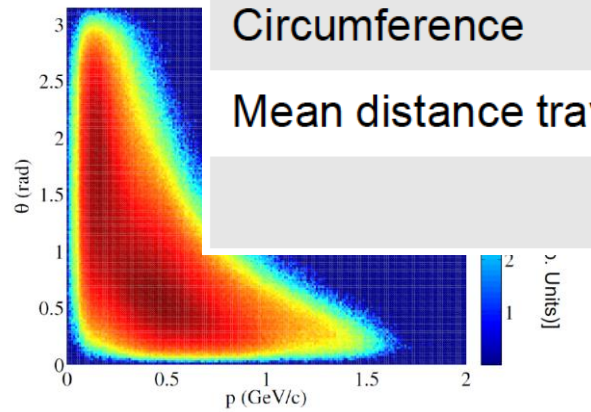
- Low ener
  and muor
- Large spr
  direction
- Fast deca
  - ✓Short pio
  - ✓Very large

	FNAL FODO	CERN FFA	ESS
Proton energy	120 GeV/c	100 GeV	2.5 GeV
Pion energy	5 GeV/c	5 GeV/c	~ 0.5 GeV/c
Muon momentum	3.8 GeV/c	3.8 GeV/c	~ 0.45 GeV/c
Momentum acceptance	±10%	±16%	
Emittance acceptance	2π mm rad	1π mm rad	
Length of decay straight	181	180	
Circumference	490	510	60-300
Mean distance traveled (μ)	24 km	24 km	2.8 km
	~ 50 turns	~ 50 turns	10-50 turns

Large energy acceptance
compensation
net bores
ce type (FFA?)

se acceptance
bores
ng beam size

Example of pion dis

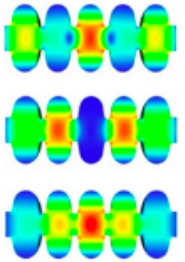


•Kickers

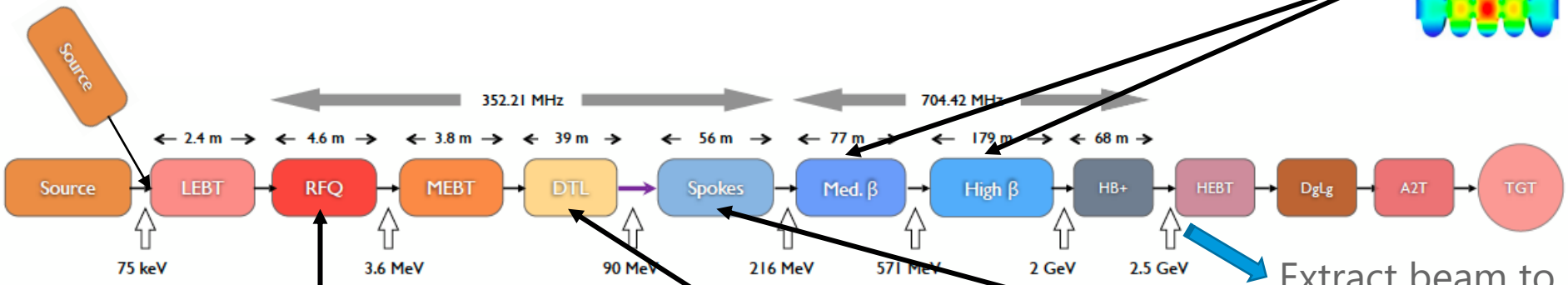
Linac Design

- 704 MHz klystrons: upgraded at end of life
- Modulators: upgraded, additional capacitor chargers
- Cryogenic system: OK at 28 Hz rep. rate

New H^- source



No problems with HOMs due to chopping pattern



Extract beam to ESSnuSB

Radiofrequency quadrupole (RFQ)

Drift tube linac

Spoke cavity Cryomodule under test at FREIA

ESSνSB+ High Level Parameters

Drivers Design:

High power	5 Mw
High availability	> 95%

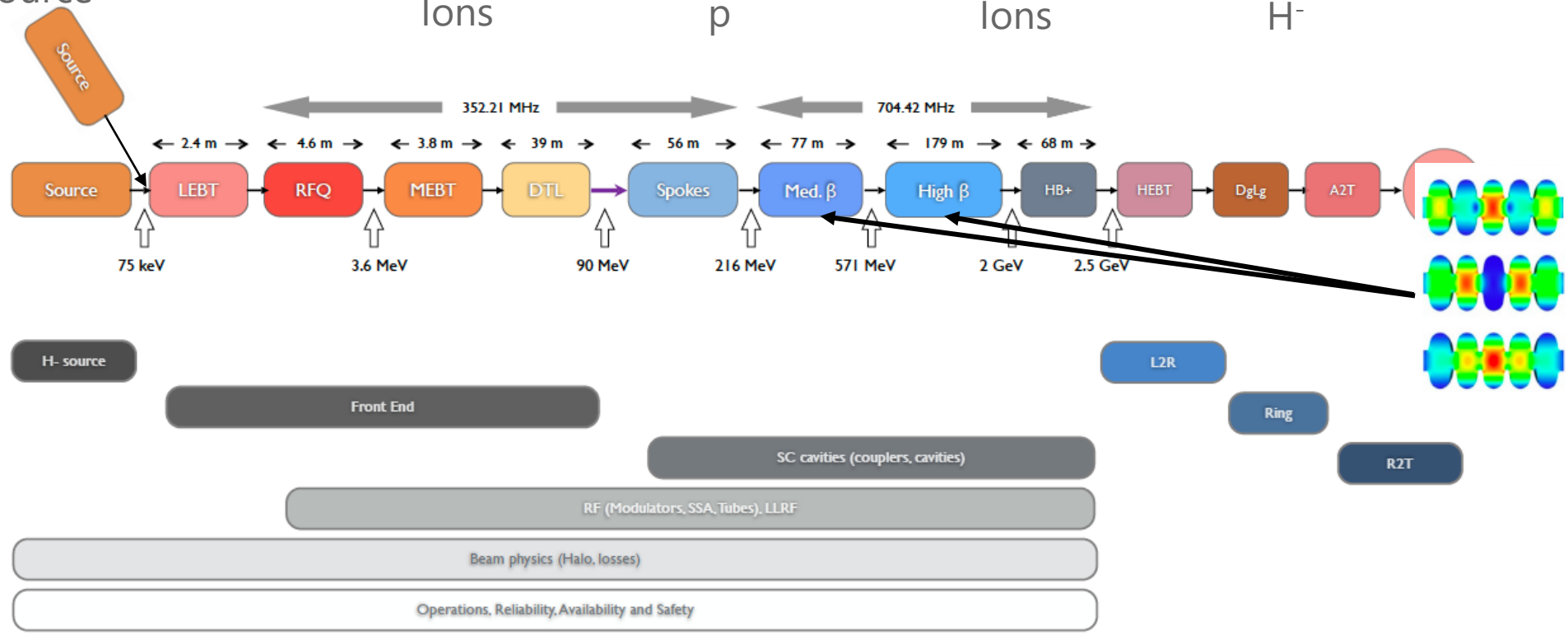
Linac Parameters:

Beam Energy	2 GeV
Beam Current	62.5 mA
Rep. Rate	14 Hz
Pulse length	2.86 ms
Losses	< 1 W/m
Ions	p

ESSnuSB beam:

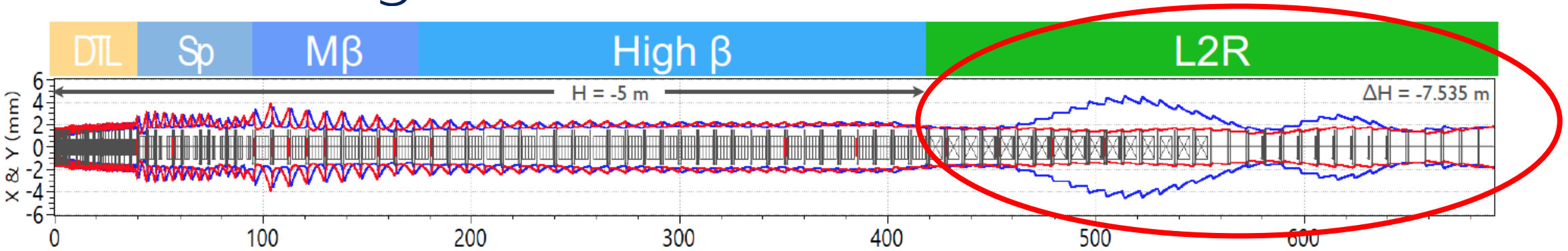
Beam Energy	2.5 GeV
Beam Current	62 mA (50 mA)
Rep. Rate	14 Hz
Pulse length	< 3.5 ms
Losses	< 1 W/m
Ions	H^-

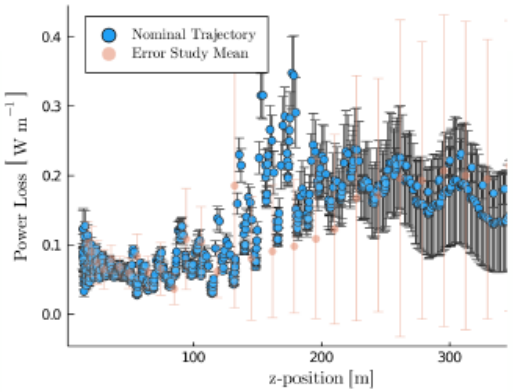
New H^- source

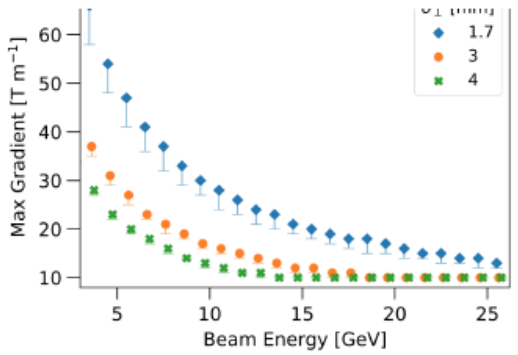


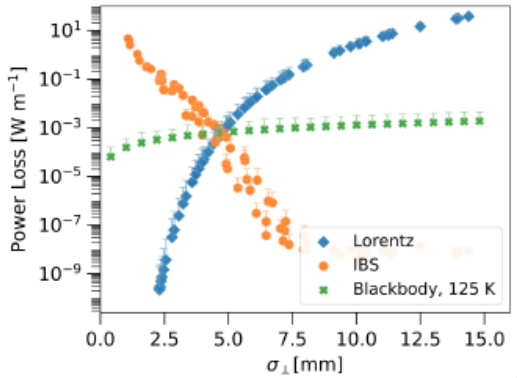
No problems with HOMs due to chopping pattern

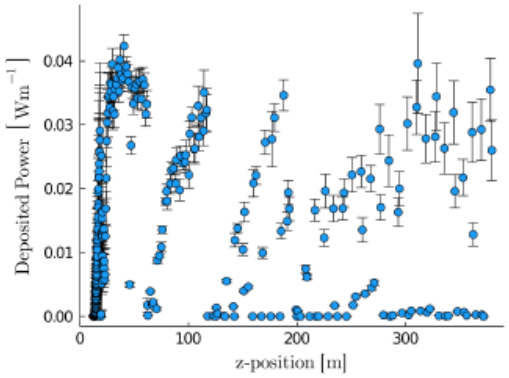
Linac Design

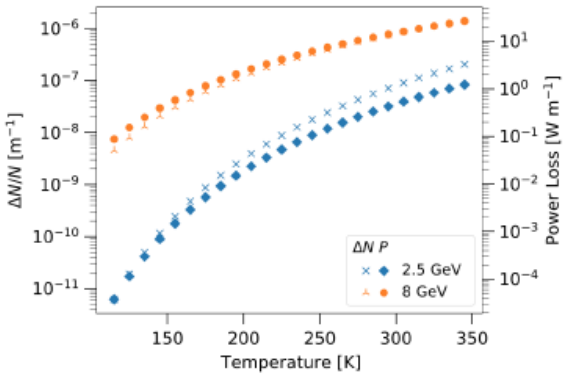


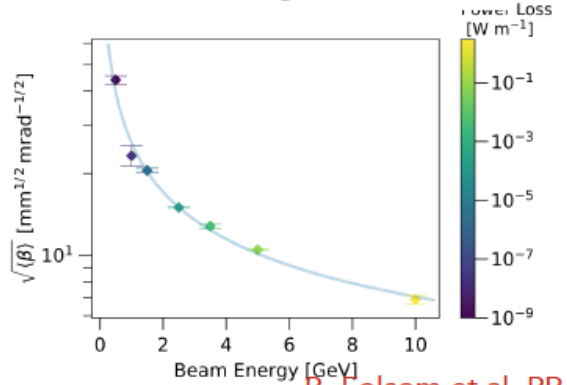












B. Folsom et al, PRAB 24, 074201 (2021)

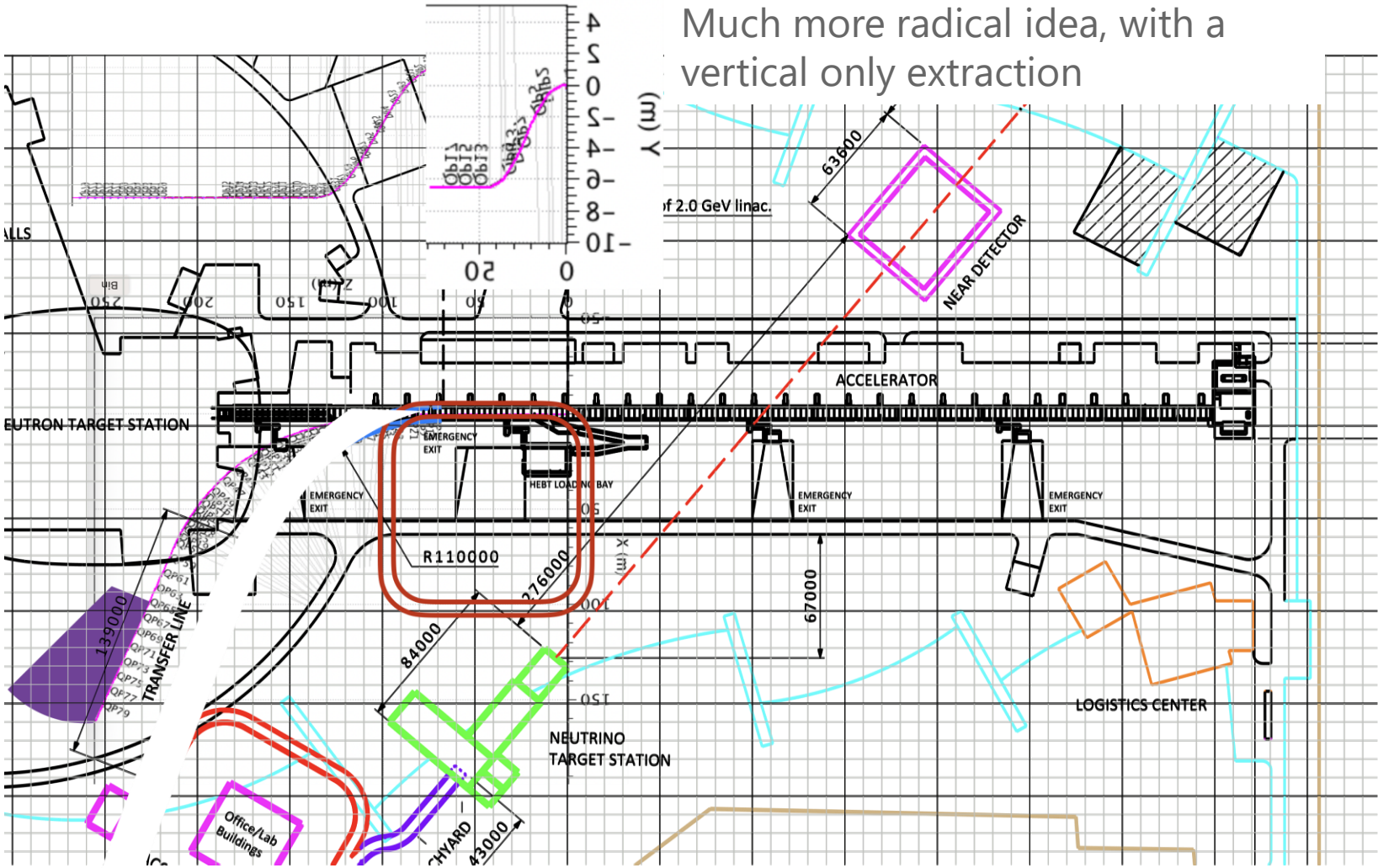
What is remaining from Linac?

L2R transport line

- From CDR: 5 Vertical and 8 Horizontal bends
- Blocks the passage on the linac tunnel (might be problematic)

- Rework: reduce the amount of dipoles and make them weaker, in order to improve the loss due to H- stripping.
- Investigate different ways to extract the beam from the linac.

Much more radical idea, with a vertical only extraction



Courtesy M. Eshraqi

Keeping an eye in the future

ESS medium pulse facility

- Feb 2023: Mini-workshop on Medium pulse length at ESS
  - A medium pulse of (100μs to) 50μs duration suits to a high gain, ~5 to 30, for the whole wavelength spectrum used at ESS instruments
- Moderator and Target:
  - Changing the pulse length has no impact on the total power and target cooling requirements, since heat transfer is slow compared to the proton pulse.
  - Moderator gain of more than 10 for wavelength below 2 Å
  - Thermomechaninal properties might be a bottle neck
- Accelerator:
  - How to go from 3 ms to 50-100 μs? An the answer is an **Accumulator ring**.
  - Can we just plug and play the ESSνSB for this job -> not clear and more study is needed

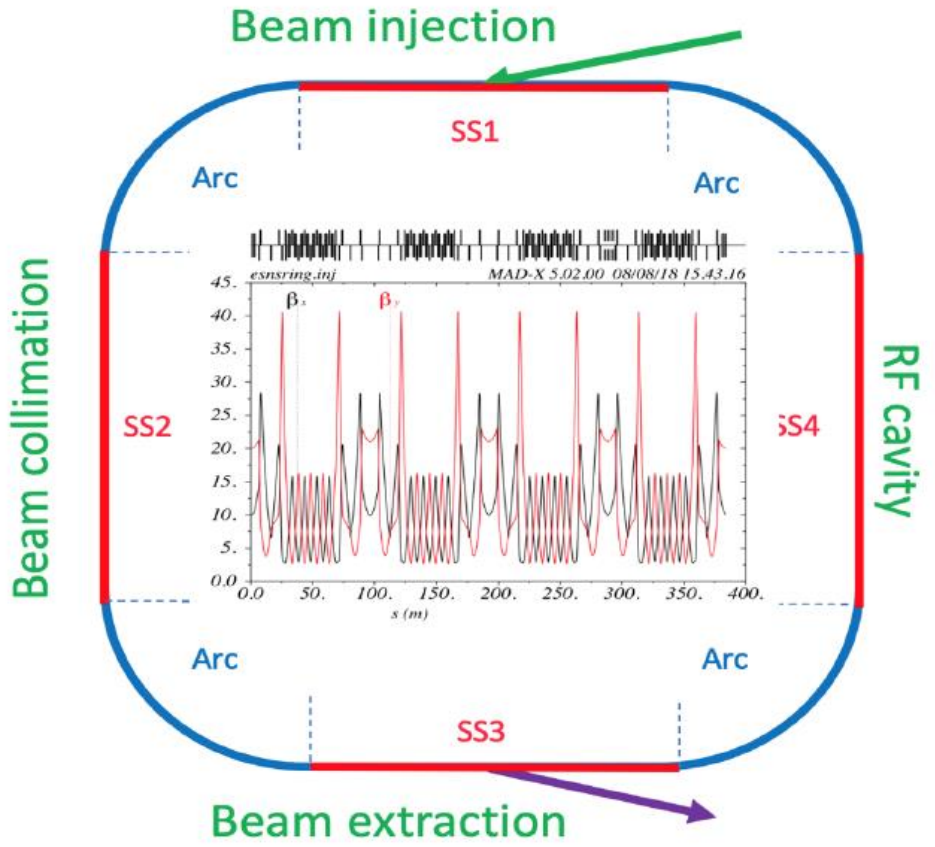
Accumulator Ring Design

Main challenges

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

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



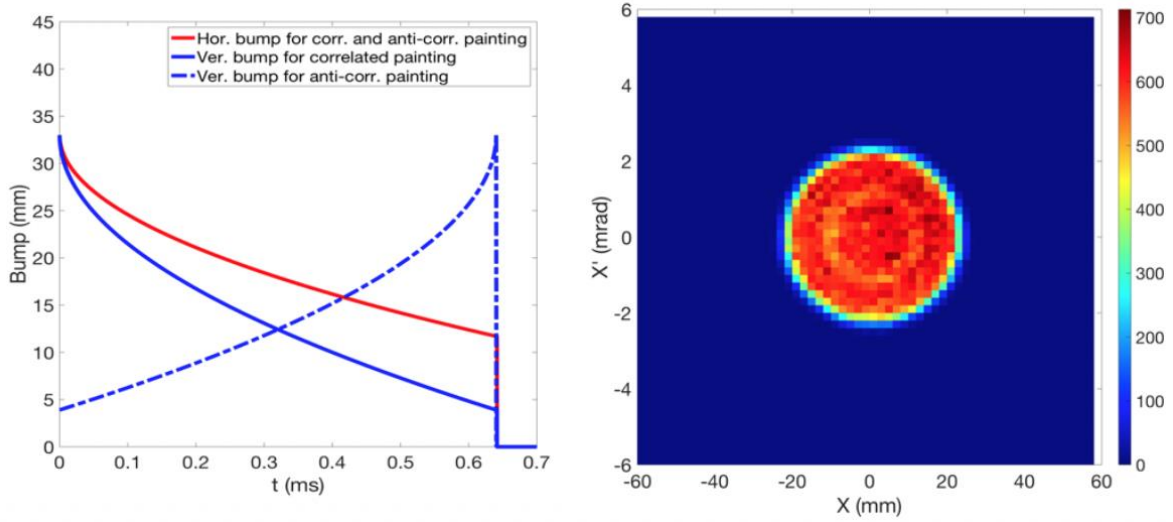
	ESSnuSB	PSB	SNS	J-PARC RCS
Ring circumference	384 m	157 m	248 m	348 m
Beam energy at injection	2.5 GeV	160 MeV	1.0 GeV	400 MeV
Beam energy at extraction	2.5 GeV	2.0 MeV	1.0 GeV	3.0 GeV
Number of injected particles	2.3e14	1.6E13	1.5E14	8.3E13

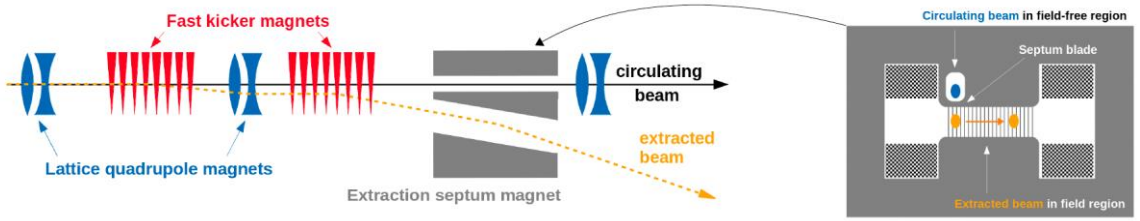
Maja Olvegård, Ye Zou

Injection/Extraction

- Foil stripping vs Laser stripping.
- To mitigate space charge and peaks in foil temperature:
  - Painting
  - Mismatch injection
  - Splitting the foil along beam direction
  - Moving injection point
- Single-turn extraction system is designed to extract the full beam in a single turn after accumulation. Various Challenges:
  - Loss-free extraction ⇒ optimize aperture sizes
  - Rise-time of kickers ⇒ aperture size, B-field, technology

Y. Zou, Uppsala University





A. Alekou and I. Efthymiopoulos, CERN

Next Steps

LEnuSTORM:

- Continue the work of the LEnuSTORM design, define a more restict set of parameters and start simulations.
- Very strong interdependece with WP3 and WP5

Overall accelerator facility:

- Further work on accumulator (Beam dynamics, RF, instabilites and Diagnostic)
- Injection and Extraction
  - Exploration of direct proton injection
- L2R transfer line re-work (cost saving, better integration on site, in touch with WP2)
- Continue the work on what is needed to run the linac at 28 Hz and ~8% duty factor
- Continue the work on source develpment (H^- source still do not meet ESSnuSB specs)

ESS neutrino Super Beam plus

Co-funded by
the European Union

Thank you!
Questions?