Accumulator Ring
for the ESS Neutrino Super Beam

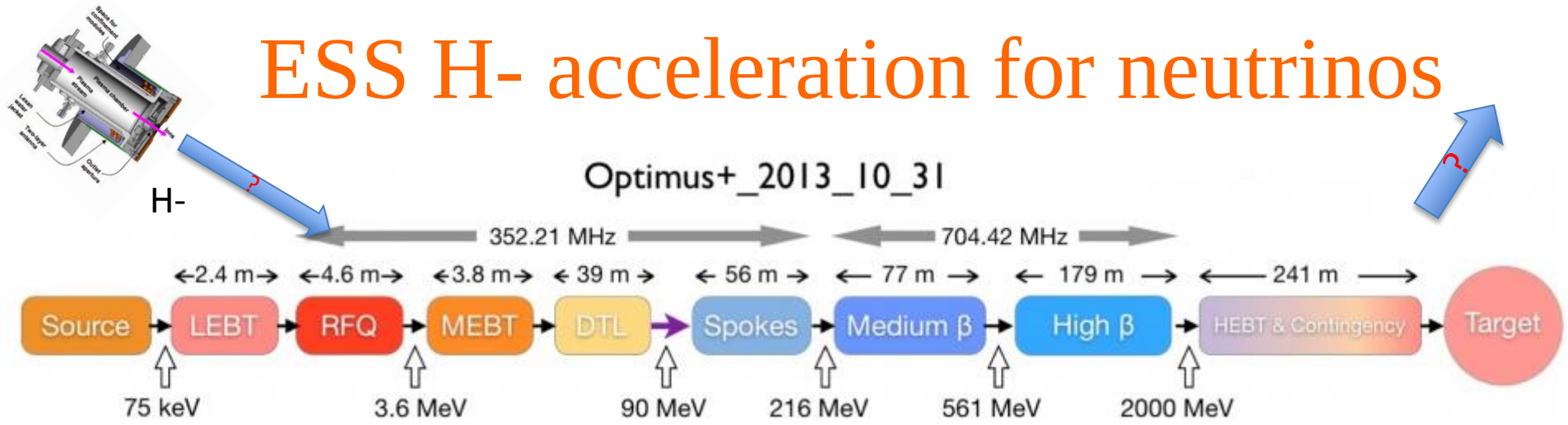
E. Wildner, CERN

Contributions

J. Jonnerby, Uppsala Univ./CERN,
M. Martini, CERN, H Schönauer, CERN

W. Bartmann, E. Bouquerel, M.Dracos, T. Ekelöf, M. Lindroos, D. Mc Ginnis, M.Eshraqi J.-P. Koutchouk, N. Vassioupolus, G. Lanfranco, Y. Papafilippo, R. Ruber and others

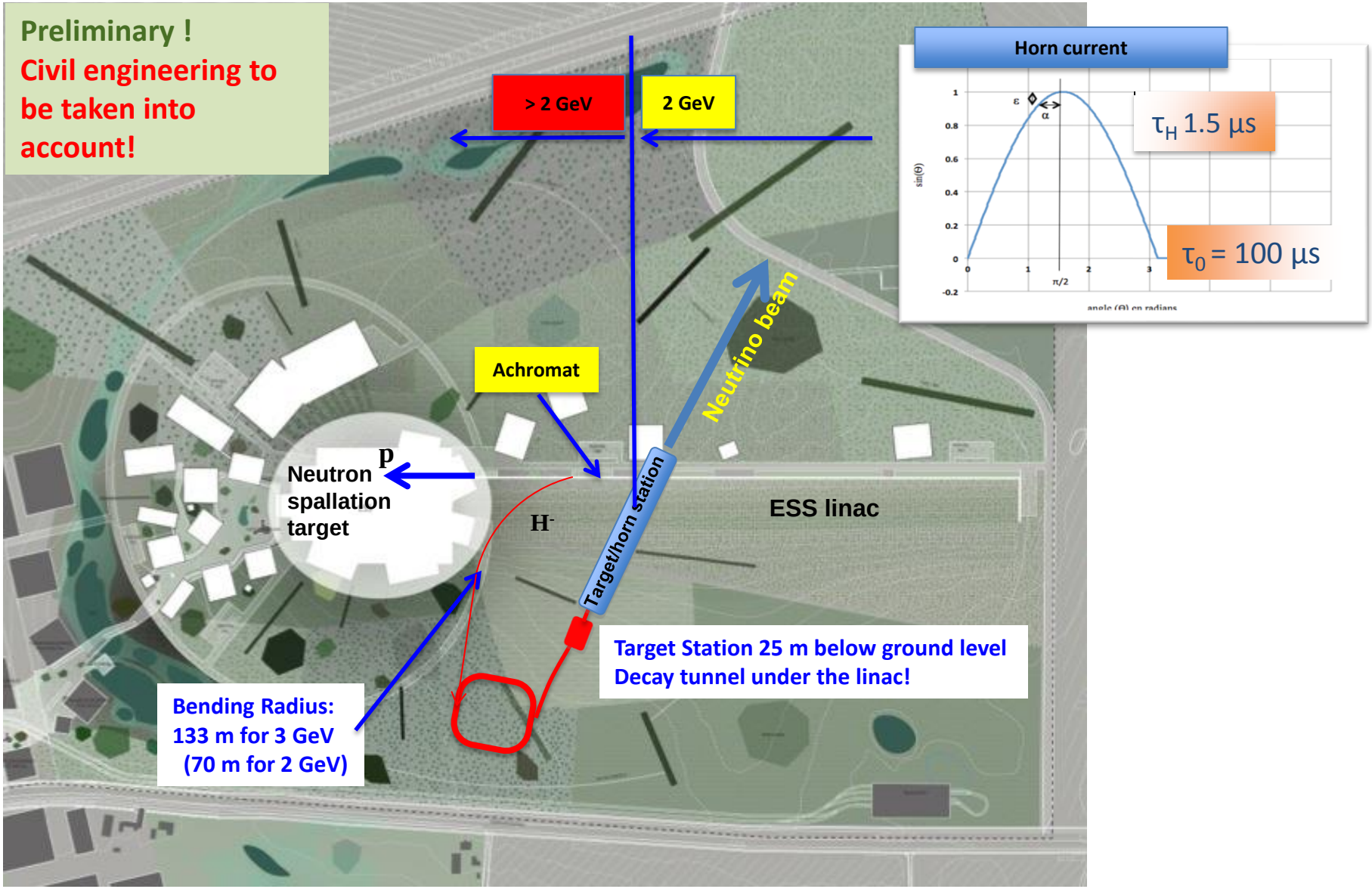
ESS H- acceleration for neutrinos



- The ESS Linac will be built for neutron spallation (proton acceleration 14 Hz)
- Duty factor low (4%); some additional capacity is available
- Repetition rate can be increased to 28 Hz, to permit an extra acceleration cycle

ESS Technical Design Report, April 23, 2013
ESS-doc-274
http://europeanspallationsource.se/documentation/tdr.pdf

ESSnuSB Accumulator



ESS Accumulator for neutrinos

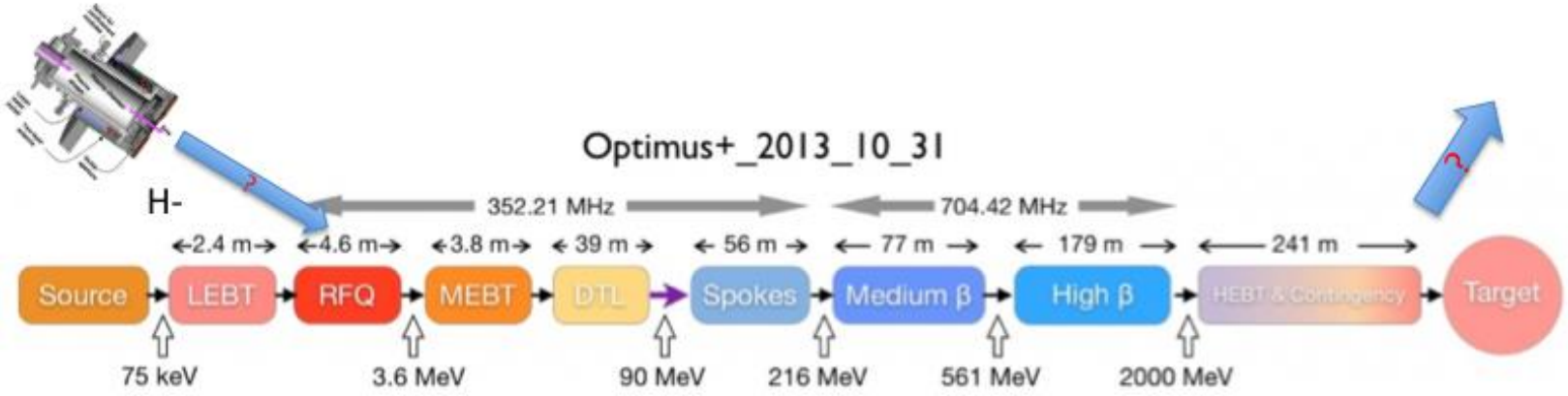
- **Constraints on present neutrino target focusing system**
- Solution**: reduce beam pulse length**
  - Compress the linac pulse in an accumulator
  - The pulse length on target < 10 μs
- **Accumulator constraints**
  - Reasonably-sized accumulator ring
  - Multiturn injection of p with high intensities
  - High intensities in the ring may cause collective effects and beam loss

Mitigate Difficulties with High Intensities

- Fraction the Linac pulse and stack the shorter pulses
  1. In space: 4 accumulators, arXiv:1309.7022v3

     or

  2. In time: shorter pulses pass consecutively one accumulator, IPAC 14, WEPRO117
- Charge exchange injection to limit multiturn losses: use H^- - ions
  - Needs an extra H- ion source
  - Merging into linac at optimal position (after MEBT?)
  - Intrabeam stripping and Lorentz stripping (linac) ?
  - Radiation



Less particles in Ring

- ESSnuSB
  - 1.25 MW on each target, 4 targets
  - Reasonable accumulator circumference of 430 m =>1.5 μs pulse length
  - 1.1 10^{15} p would give SC of -0.67 (round beam, 2.0 GeV, 100 π mm mrad)
  - In each ring 1.1 10^{15}/4 => 2.75 10^{14}
  - In one ring: For 2.75 10^{14} protons in machine SC < – 0.2 (acceptable)
  - Cf SNS, C = 220 m, 200 π mm mrad, 2.0 10^{14} protons , …. ΔQ=-0.3, Bf = 0.4

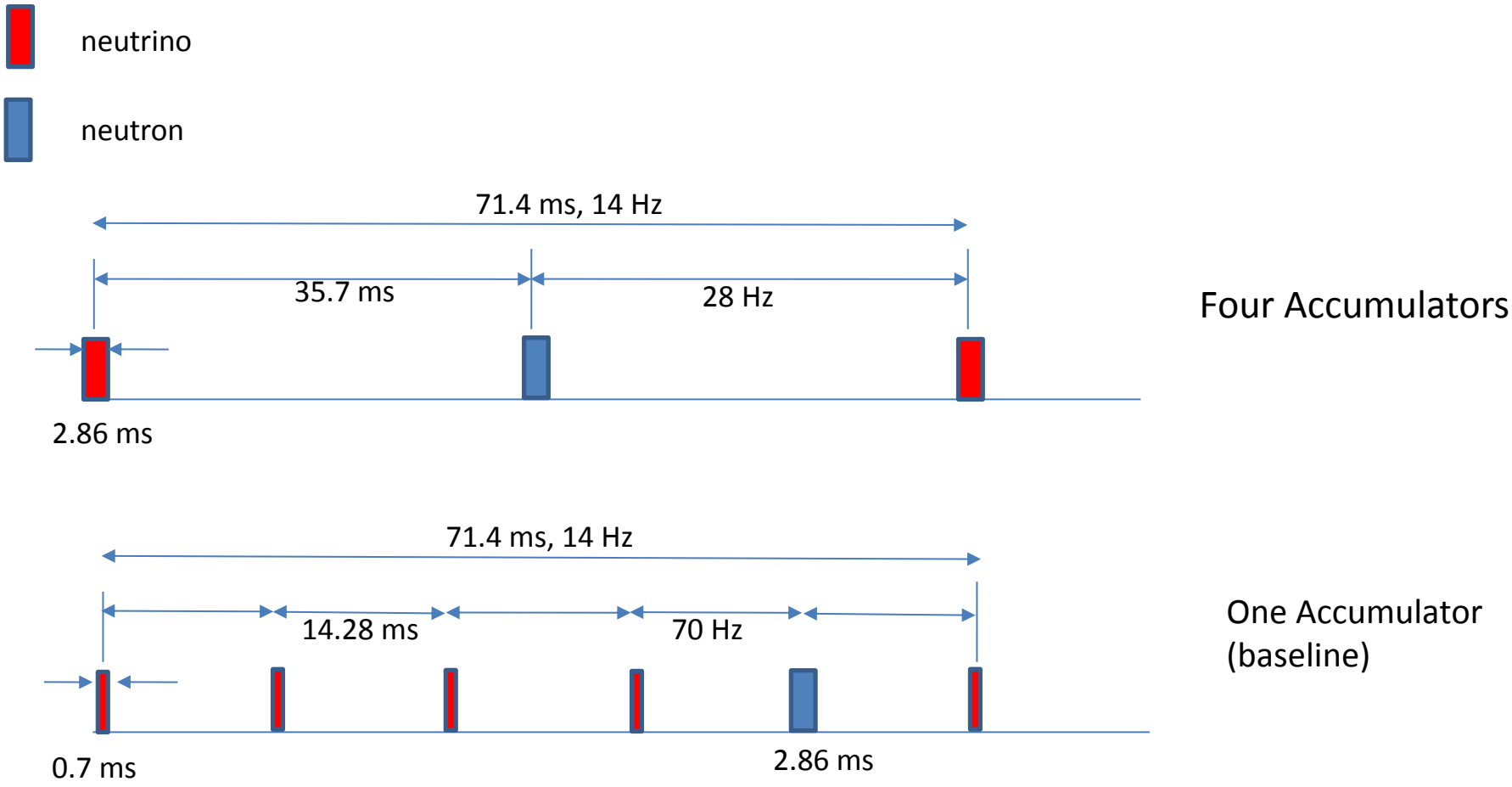
$$\Delta Q_{x,y} = -\frac{r_0 N}{2\pi E_{x,y} \beta^2 \gamma^3} \cdot Bf$$

One accumulator

- 4 Accelerators for accumulation seem costly and not necessary
  - One accumulator could pulse 4 times with ¼ of the linac pulse length
- The injection bumper is slow
  - Rise time for the PS Booster bumpers is10 ms (same for the fall time)
- We propose to make 4 spaced linac pulses of length 2.86/4 ms (same beam power)
  - They would be injected sequentially into accumulator
  - Linac pulses paced such that bumpers are comfortable
  - However a price has to be payed…

NB: accumulation for ESS neutrons need H- but considerably longer pulses at extraction from accumulator: this is not forgotten but is less straight forward, needs more design work

Linac Pulsing 70 Hz, baseline

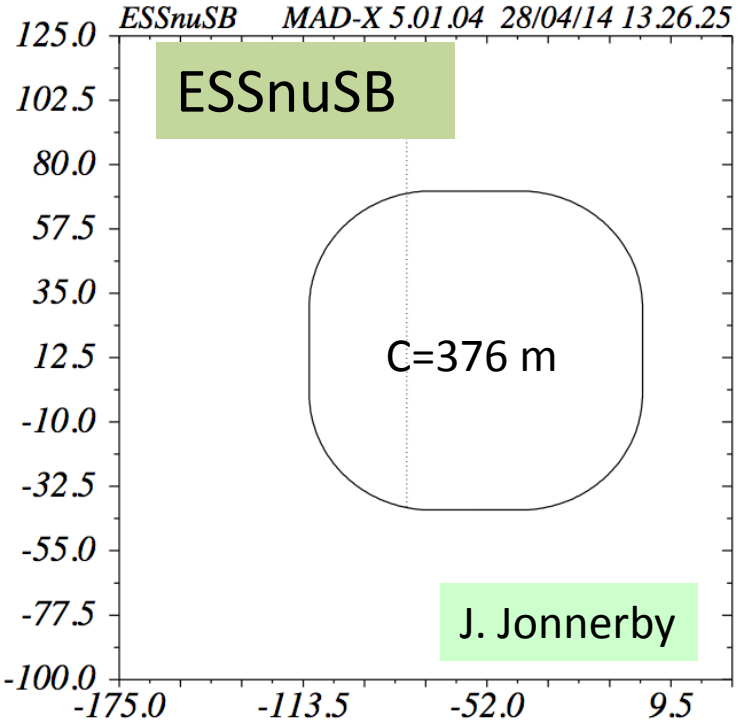


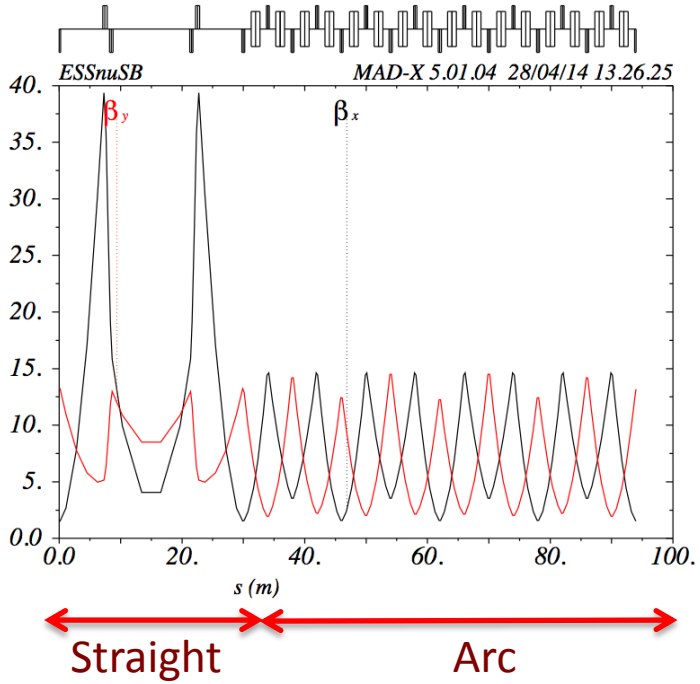
70 Hz linac pulsing

Fill time of the superconducting cavities:

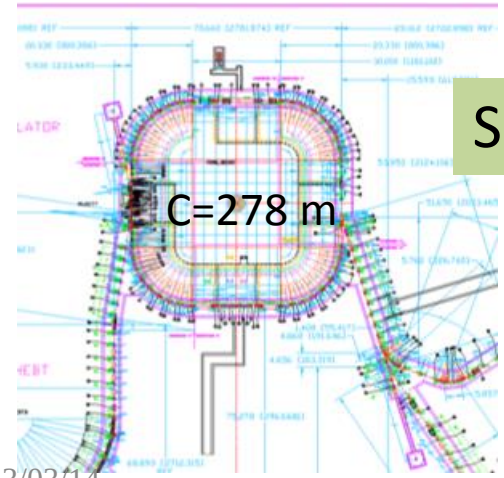
- For loaded Q, this is about 0.2 ms
- For two 3 ms beam pulses, this is 6.6% of the beam pulse length
  This corresponds to an inefficiency of 6.6%
- 4 pulses at 0.75 ms and one pulse of 3 ms: Communication D. Mc Ginnis
  5 x 0.2 ms = 1 ms filling time, 16.6% inefficiency (10% extra)
- Keep in mind: 4 rings are 4 times operation and maintenance cost, not less
- Can it be technically achieved (see below review by F. Gerigk and E. Montesinos)?
- Foil heating in accumulator (see later)

ESSnuSB Accumulator Lattice





Circumference	376 m
Dipole field	0.635 T
# Dipoles	64
# Quads	84
Bending radius	14.6 m
Injection region	12.5 m
Revolution time	1.32 μs



SNS straight section for injection used "as is" for simulations of foil stripping

Less bending strength to ease energy upgrade

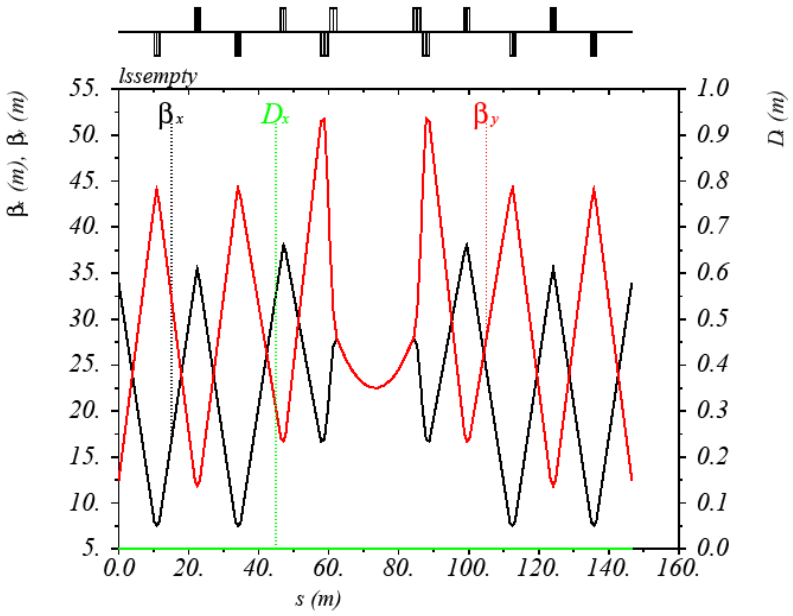
No magnet considerations yet

Collective effects not yet completed

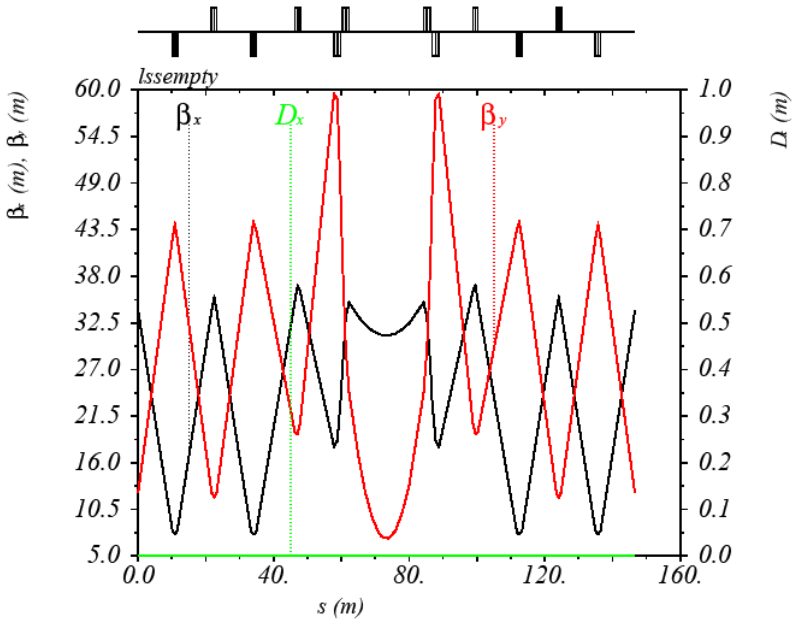
Injection area optics (foil/laser)

- Contradicting requirements for foil and laser → two different optics settings (however: the layout is the same!)

Foil optics



Laser optics



Courtesy W. Bartmann

Feasibility of Stripping foil injection

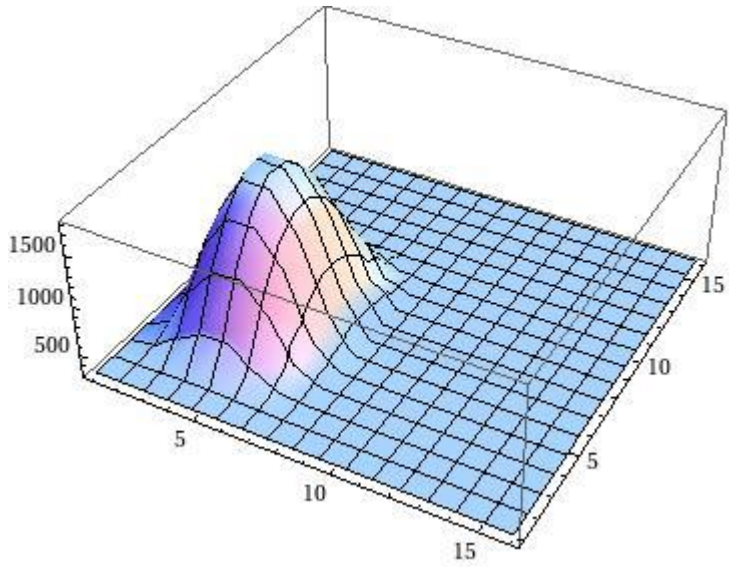
- Foil stripping feasibility: first stage approach

  - Simulations of MW accumulator projects have been done with the ACCSIM Code.
  - The results are compared with the ORBIT results (courtesy M. Plum, J. Holmes) for representative SNS beams.
  - Results also compared to a simple analytical model of the heat equations.

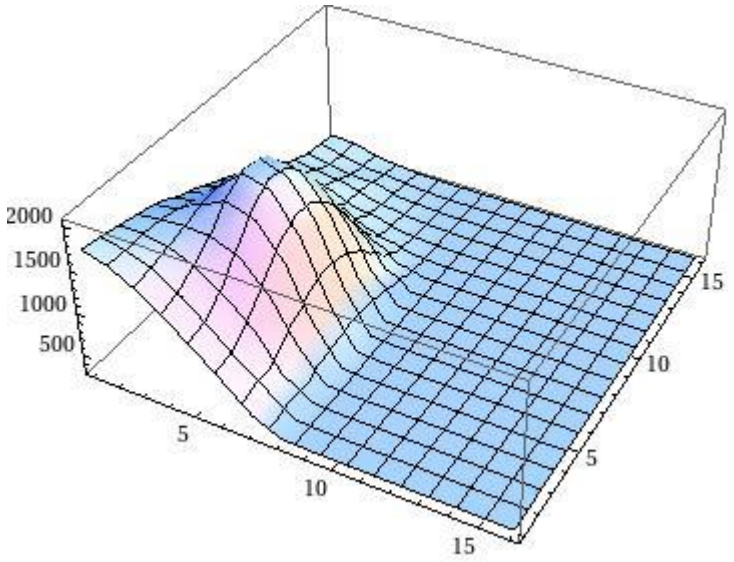
H. Schönauer & M. MartiniCERN

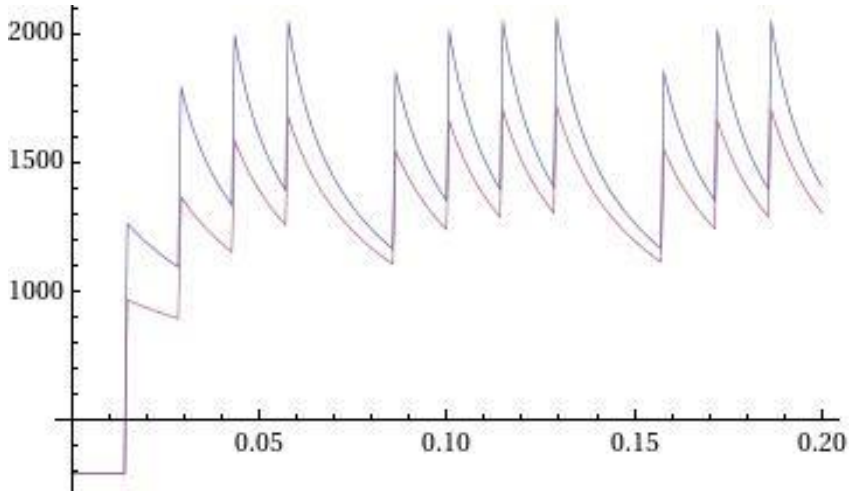
ESS Foil (Extended SNS Lattice): Peak Temperatures

H- Linac



H- Linac+ p circulating

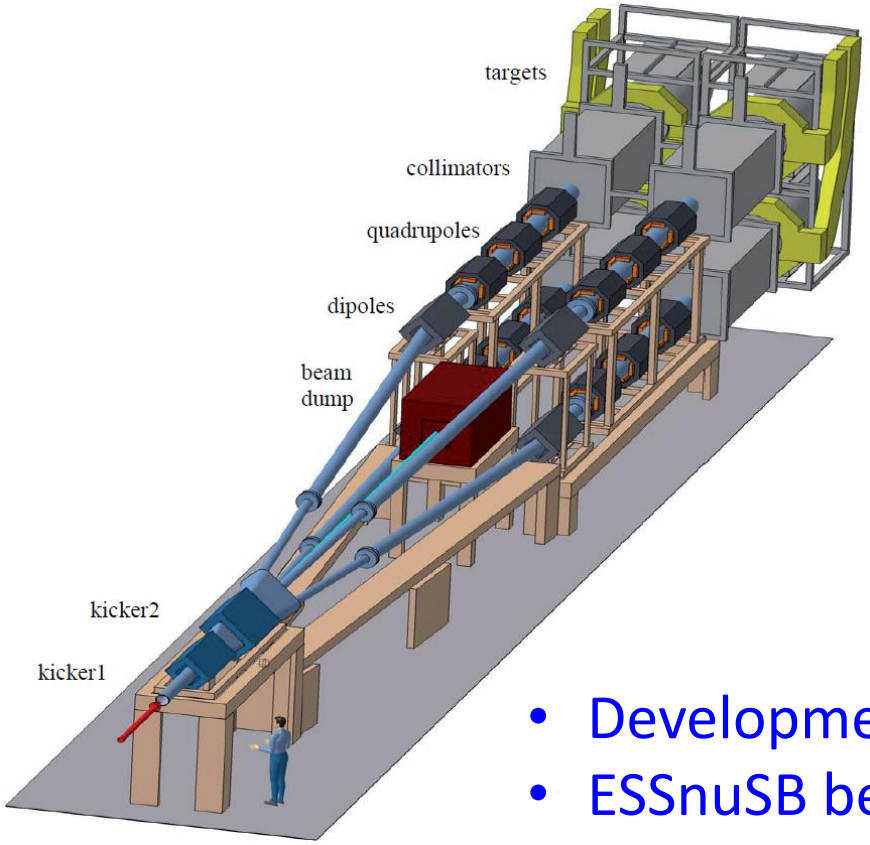




Maximum Foil Temperatures:
1797 K (H- Linac Beam))
2050 K (H- + p circulating Beam)

H. Schönauer, CERN

Extraction to 4 targets: Switch-yard



E. Bouquerel

- Development for EUROSB
- ESSnuSB beam energy is lower
- Extraction timing is different (50 Hz -> 70 Hz)
- Needs ~ 100 ns gap in Accumulator
  - Regular gaps in linac beam (chopping)

Accumulator specific requirements

H- injection is needed for efficient Injection into Accumulator

- H- source RFQ and MEBT and racks (reserve space)
- Beam steering magnets for pulsed operation are included in quads, separate them!
- Stripping losses max 0.1 W/m
- 75 % dipole filling, 3 GeV 133 m bending radius (70 m for 2 GeV)

Neutrino beam direction

- If to the north, target and decay pipe have to be sufficiently deep, crossing of linac
- Risks for ground water
- Urgent study

Fast pulsing, 70 Hz

- Operation of piezos more difficult (Lorentz-Force induced ringing of the cavities will be more dominant at the beginning of the next pulse). Needs testing!
- Check this pulse pattern does not induce HOMs in SC Cavities.

Front-End

- Assessment of injecting H- before RFQ, this includes study of chopping and matching in the MEBT for p and H-
- Check cooling capacity for for RFQ and all normal conducting cavities
- Reserve necessary space

Extracted from review F. Gerigk, E. Montesinos, 30 June 2014

Work (-packages) for EU call

1. **Accumulator design, extraction, collimation and beam dynamics**
2. **Laser stripping of H- (establish collaboration), injection design**
3. **Transfer lines (Lorentz' stripping considered) and switch-yard update**
4. **Layout and civil engineering of accumulator and transfer lines**
   a. **Should be done with on-site expertise (local rules and guidelines)**

Summary

- One accumulator: collaboration with ESS linac experts
- Lattice design: based on SNS, used for simulations
- Laser stripping : 2025? CERN synergies ?
- Foil stripping solutions (necessary fallback): possible
- Need to select subjects out of work-list for the EU call
- Accumulator should be flexible (for ESS neutrons ?)