ESS NEUTRINO SUPER BEAM

Funded by the Horizon 2020 Framework Programme of the European Union

ESSnuSB from source to target and plans for the future

NuFact 2022

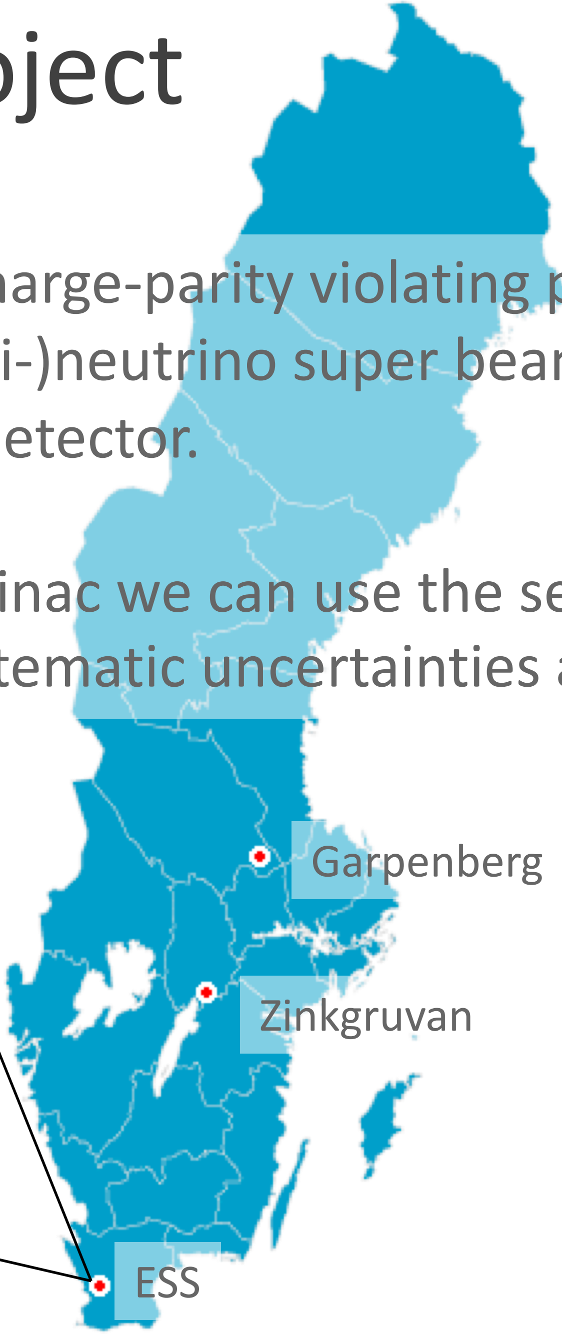
PRESENTED BY NATALIA MILAS

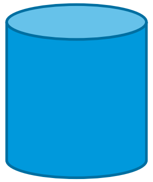
2022-07-14

The ESSnuSB Project

Goal: to measure the leptonic charge-parity violating phase
How: by generating a muon (anti-)neutrino super beam and look at the electron neutrino appearance in a large detector.

With 5 MW beam from the ESS linac we can use the second oscillation maximum where we are less limited by systematic uncertainties and thus have a higher sensitivity.





MEMPHYS type water Cherenkov detector

ESSnuSB High Level Parameters

Drivers Design:

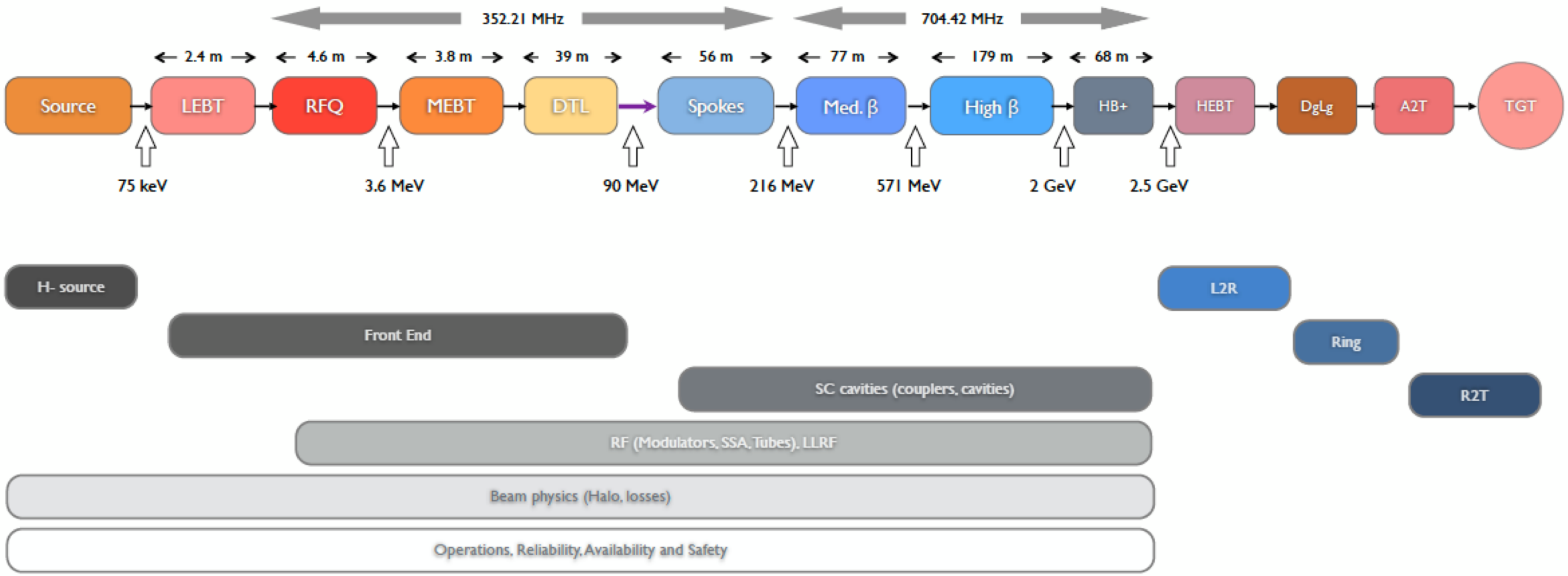
High power	5 Mw
High availability	> 95%

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

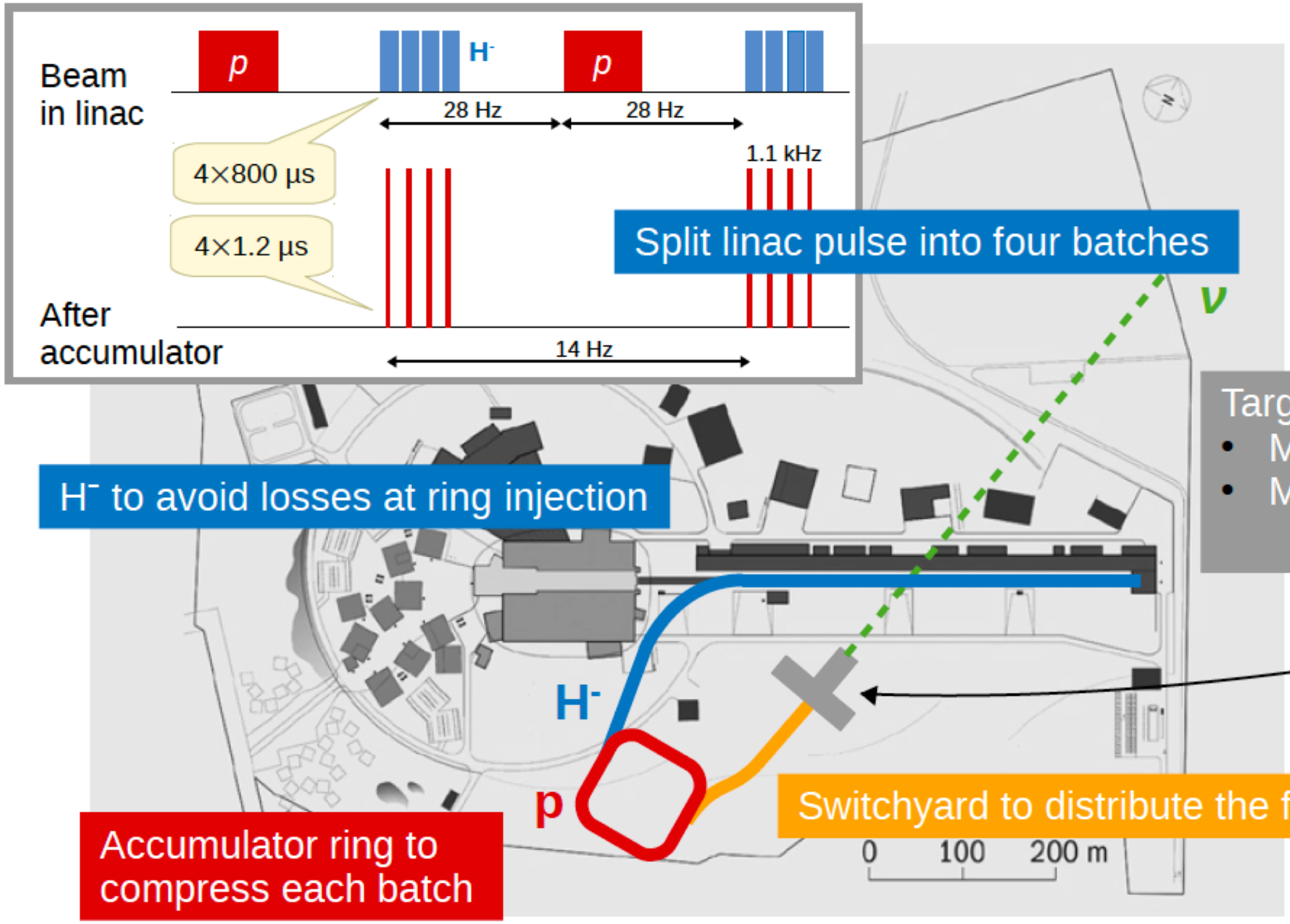
ESSnuSB beam:

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^-



ESSnuSB High Level Parameters

Constraints

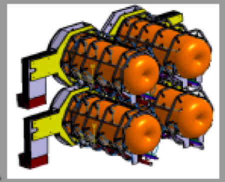


Design criteria:

- 5 MW proton beam on target
- No interference with neutron program
- Beam loss <1 W/m

Target and horn

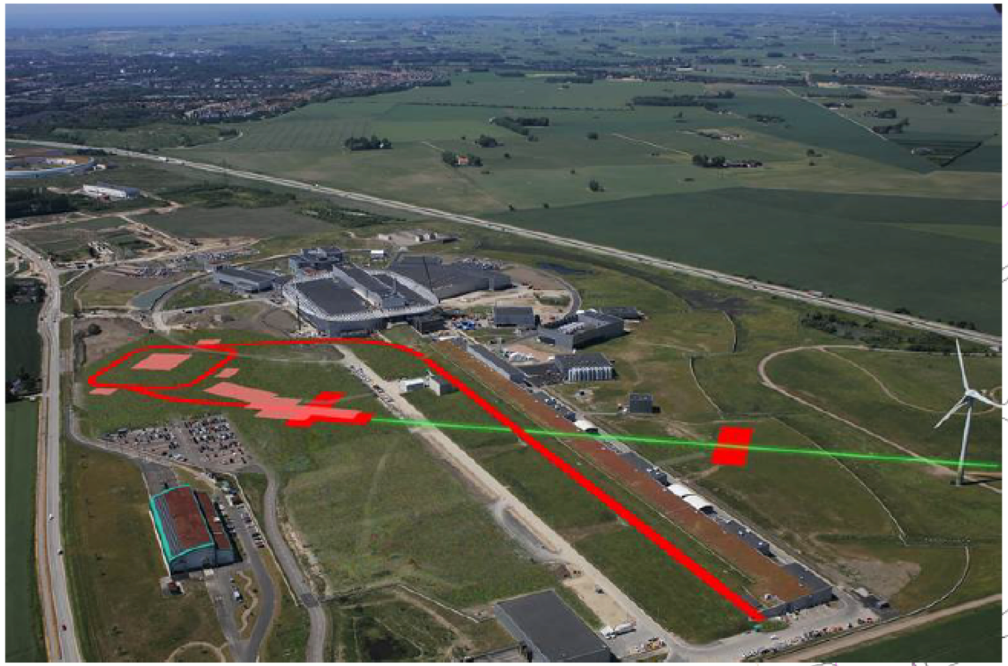
- Max 1.7 MW beam power
- Max ~1.5 µs pulse duration



ESSnuSB target station based on the EUROnu study, E. Baussan et al, IPHC Strasbourg

EssnuSB Layout

ESS NEUTRINO SUPER BEAM

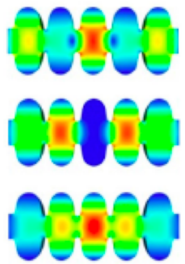


Rasmus Johansson and Nick Gazis

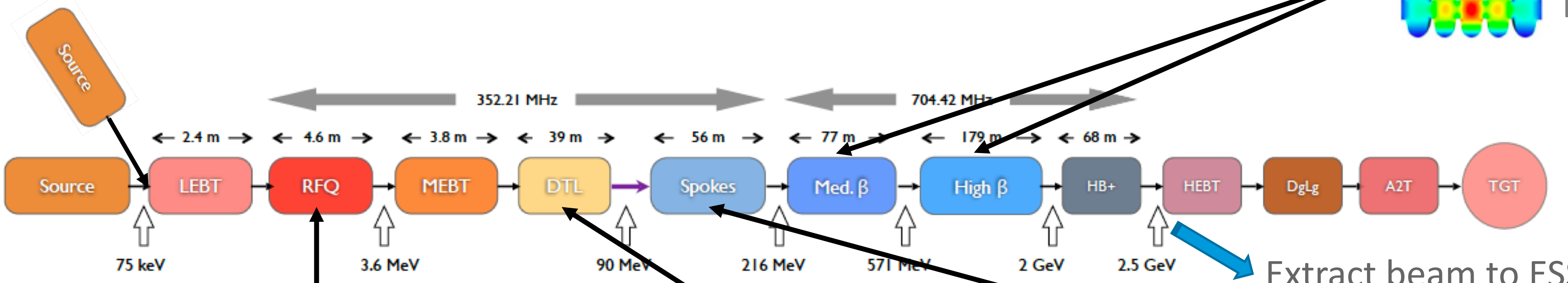
Linac Design

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

New H^- source

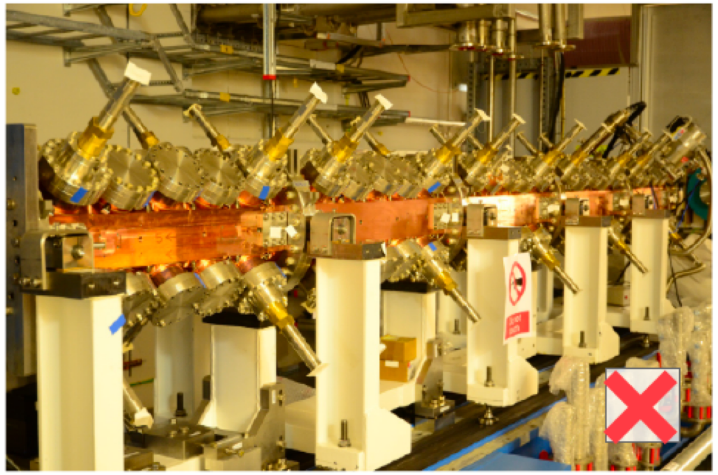


No problems with HOMs due to chopping pattern



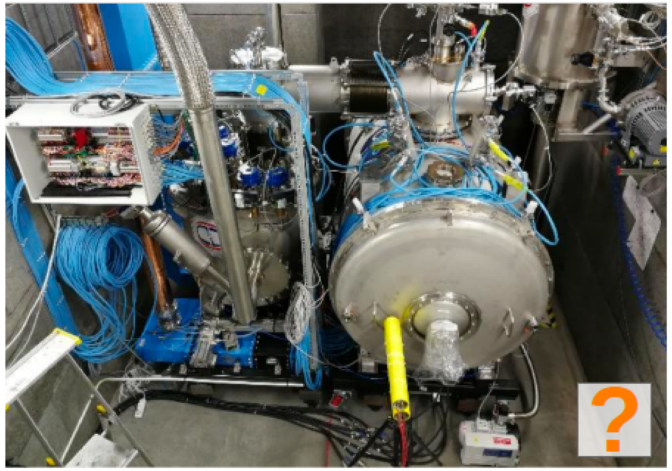
Extract beam to ESSnuSB

Radiofrequency quadrupole (RFQ)

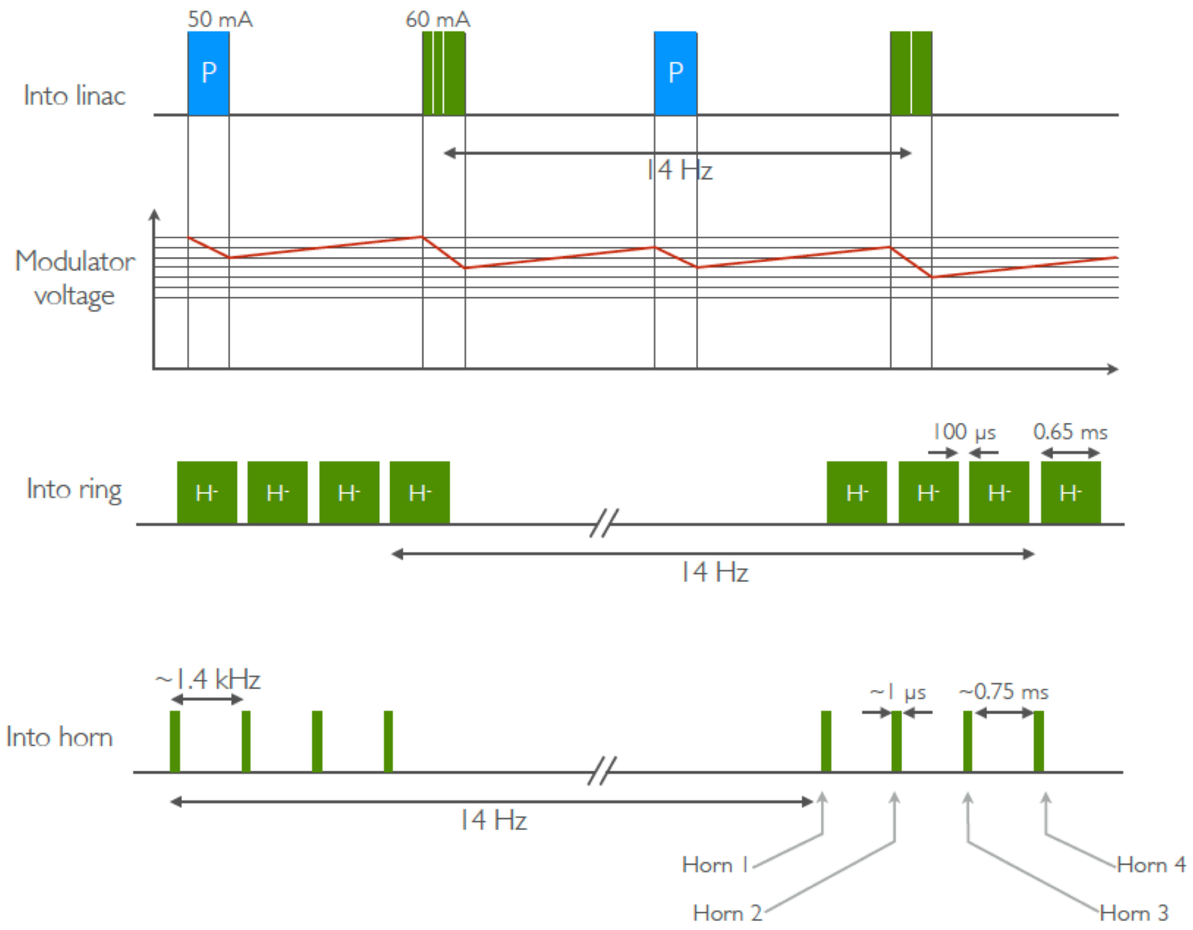


Drift tube linac

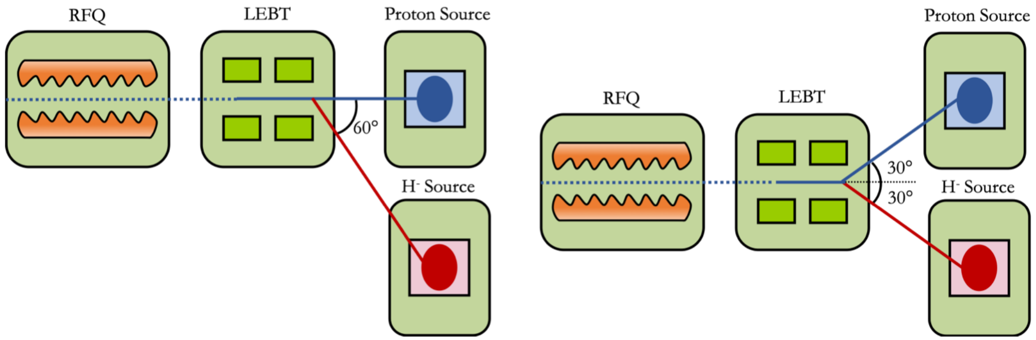
Spoke cavity Cryomodule under test at FREIA



A New Front-End and Pulsing Scheme



Possibility of merging the two bean before the RFQ



- Smaller footprint and easier to fit in the tune
- More difficult dynamics for both beam with the 30 deg option

Linac Design

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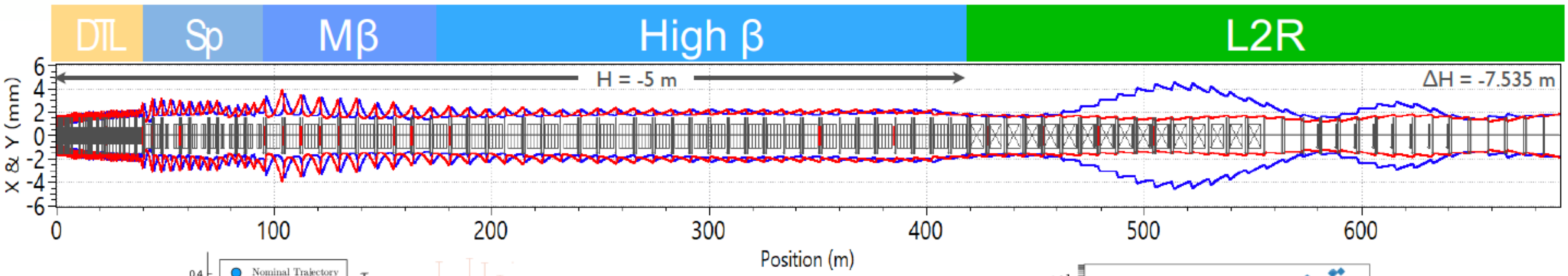
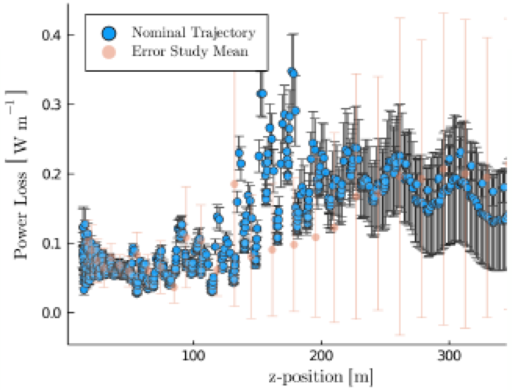
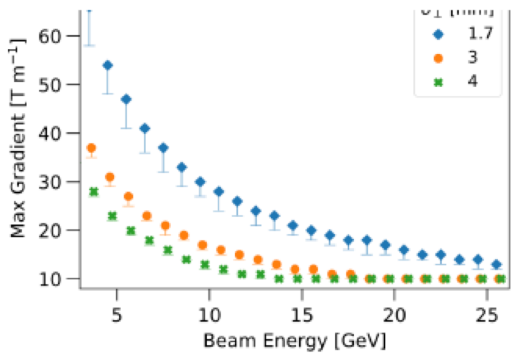
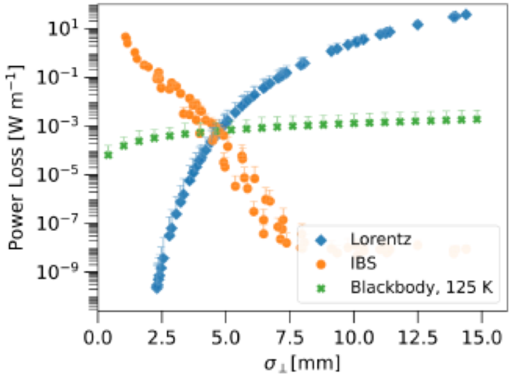
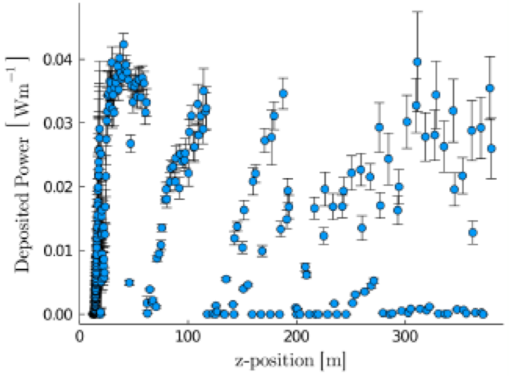
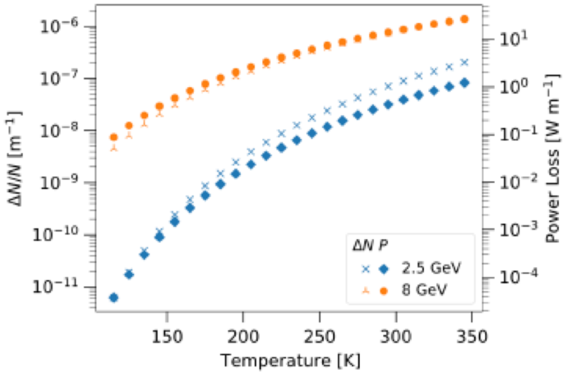


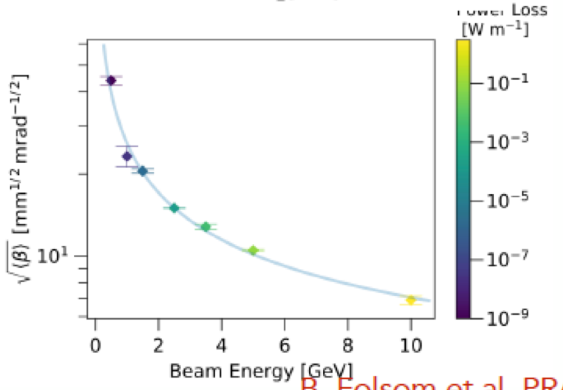












B. Folsom et al, PRAB 24, 074201 (2021)

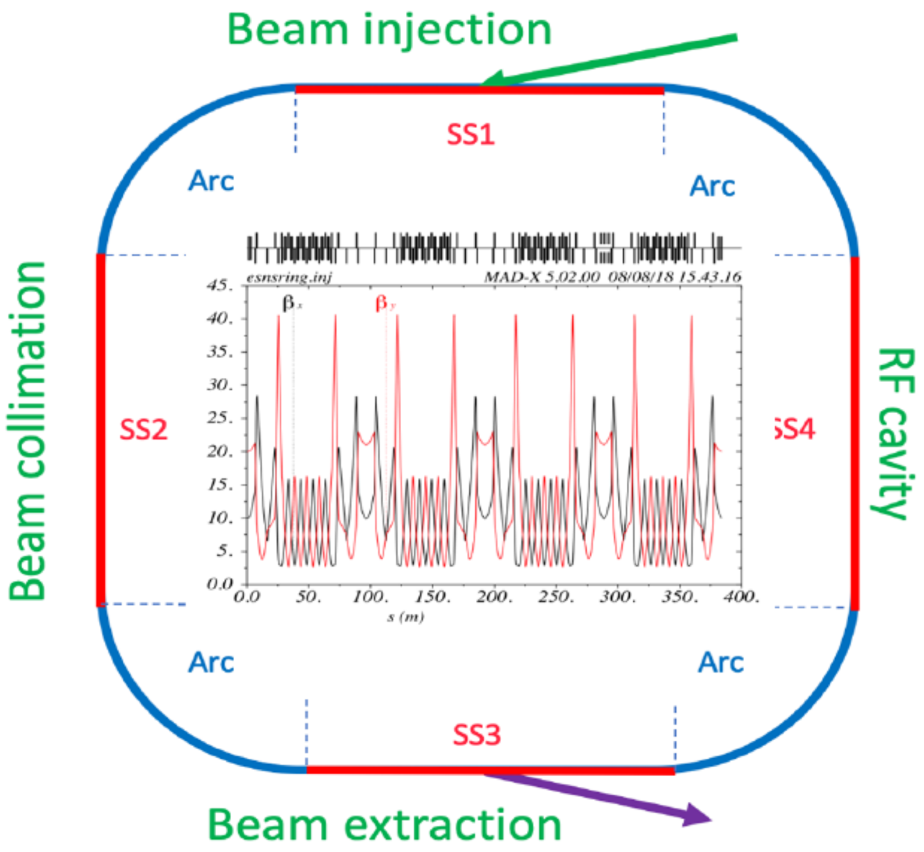
Accumulator Ring Design

Main challenges

- Beam loss control due to very high beam powe
- 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

Accumulator Ring: Injection

Foil stripping and laser stripping

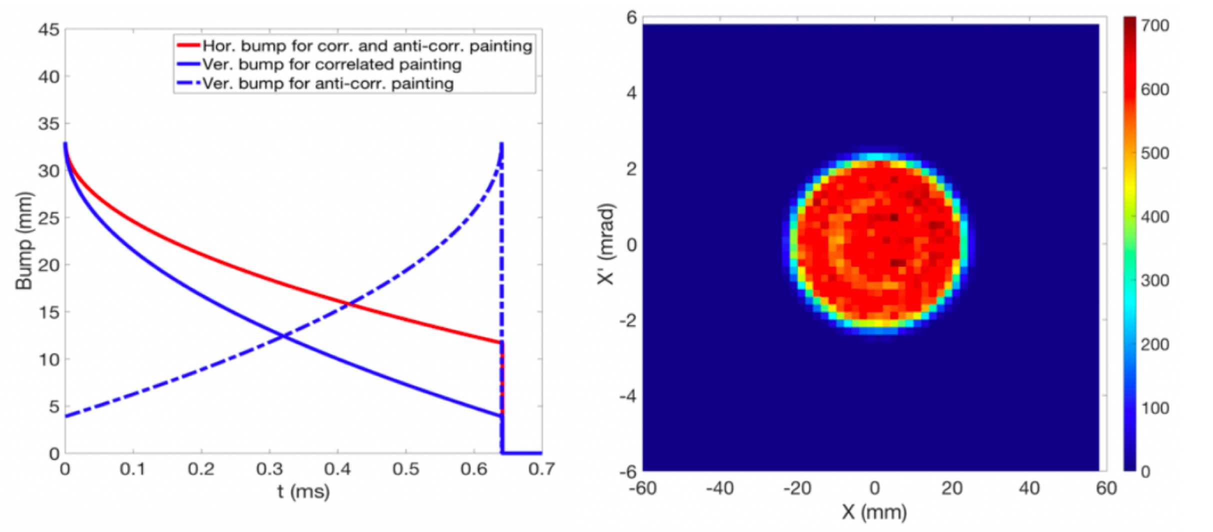
- Foil stripping: widely used in proton synchrotrons or accumulators, very challenging due to high power
- Laser stripping: a promising alternative method

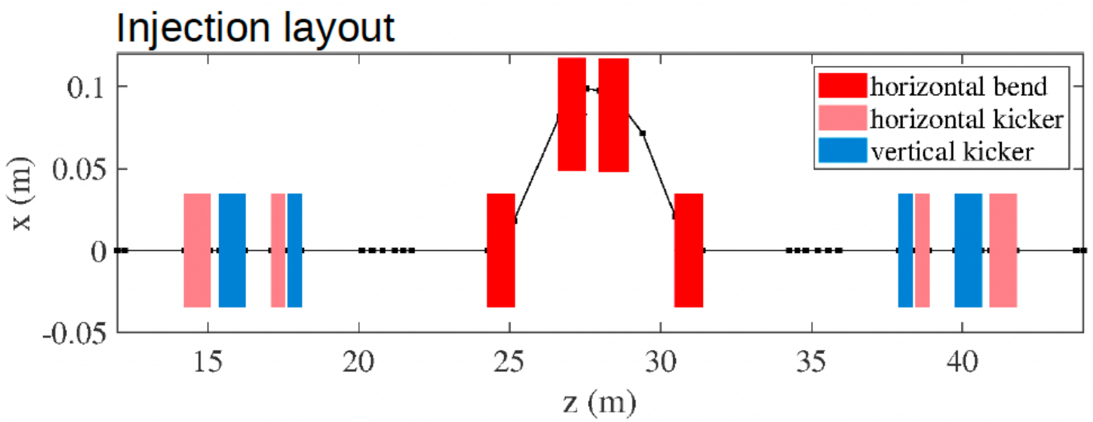
Painting

- Mitigate space charge issue
- Mitigate foil temperature issue

Foil temperature issue mitigation

- Mismatch injection
- Splitting the foil along beam direction
- Moving injection point



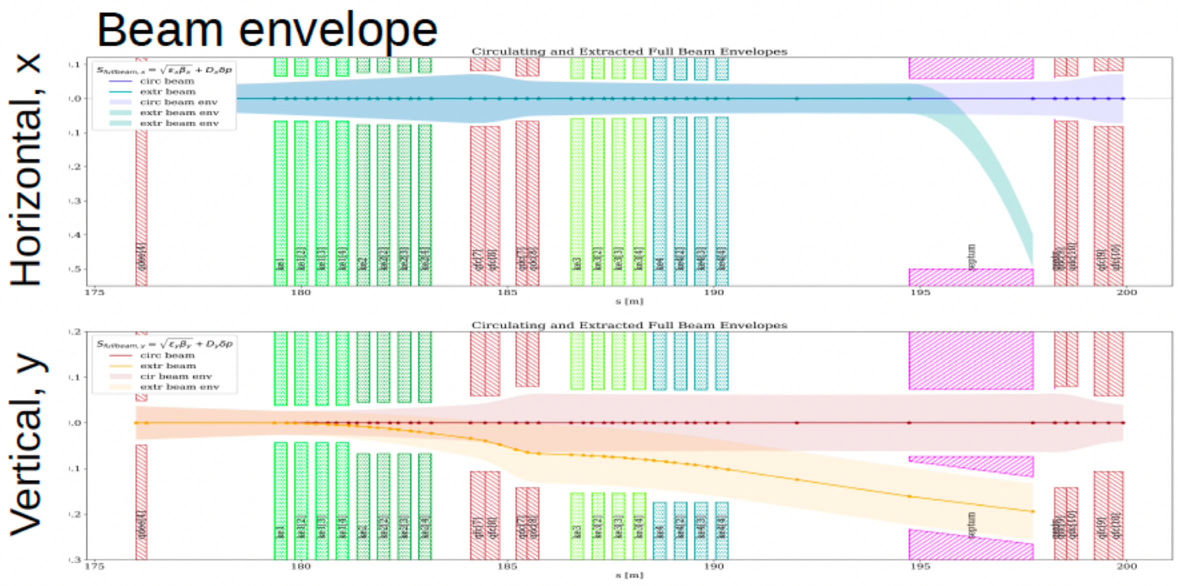


Y. Zou, Uppsala University

Accumulator Ring: Extraction

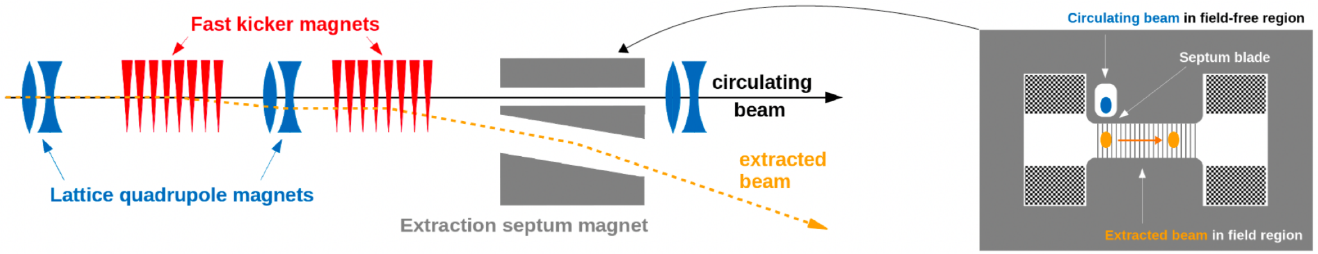
Beam extraction

- Single-turn extraction system is designed to extract the full beam in a single turn after accumulation
- Fast magnets (kickers) to extract the beam vertically out of the ring during the extraction gap of 100-130 ns
- Horizontal deflector (septum) to deflect the beam by 16.8 deg to the start of the extraction line



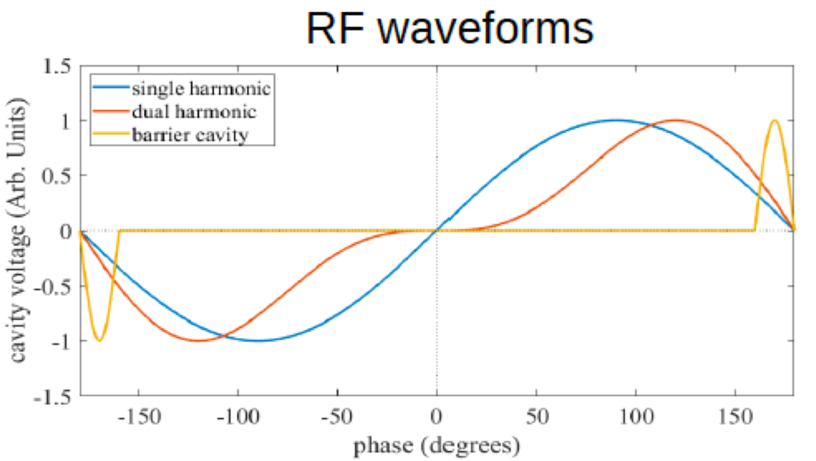
Challenges

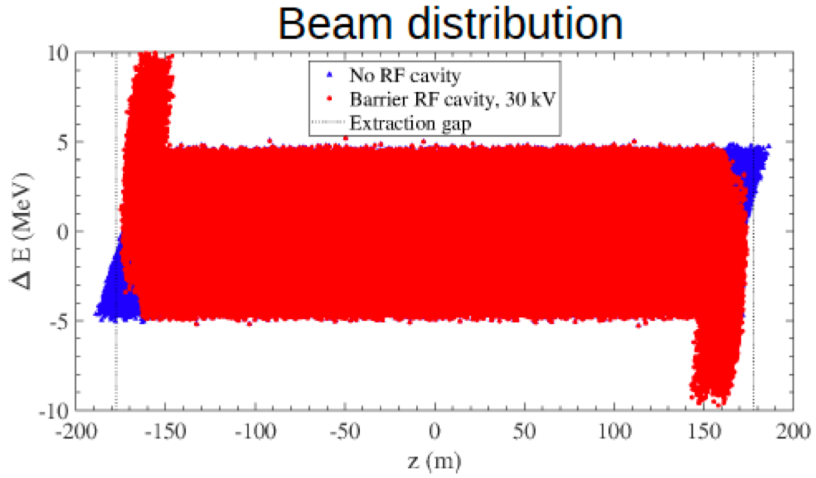
- Loss-free extraction ⇒ optimize aperture sizes
- Rise-time of kickers ⇒ aperture size, B-fie , technology



A. Alekou and I. Efthymiopoulos, CERN

Accumulator RF and Switchyard Design

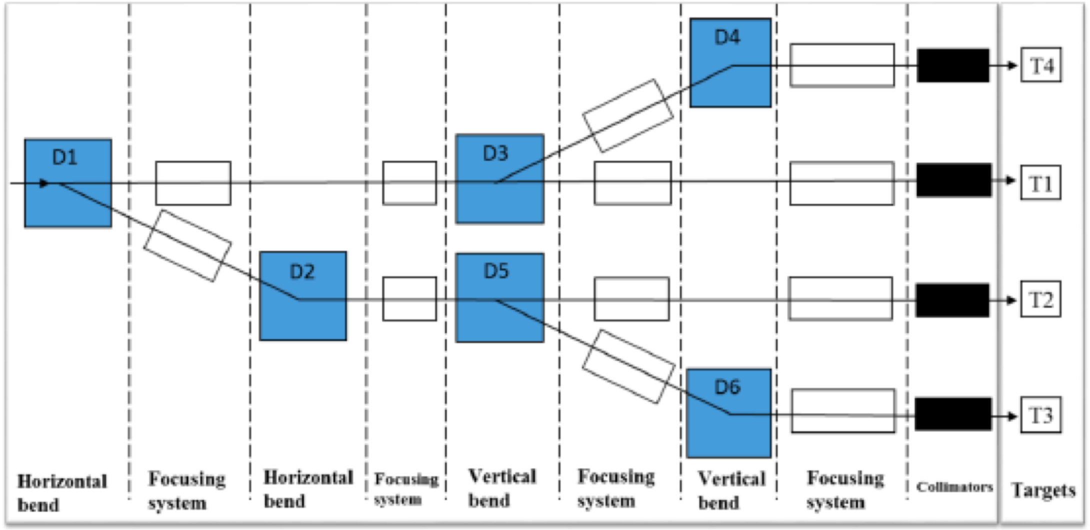




Y. Zou, Uppsala University

RF cavity

- RF cavity to keep the extraction gap clean while keep energy spread small
- Barrier bucket is chosen due to its very small leakage risk and small energy spread (±0.15%)
- Aperture optimized to make rise-time requirement easier to reach

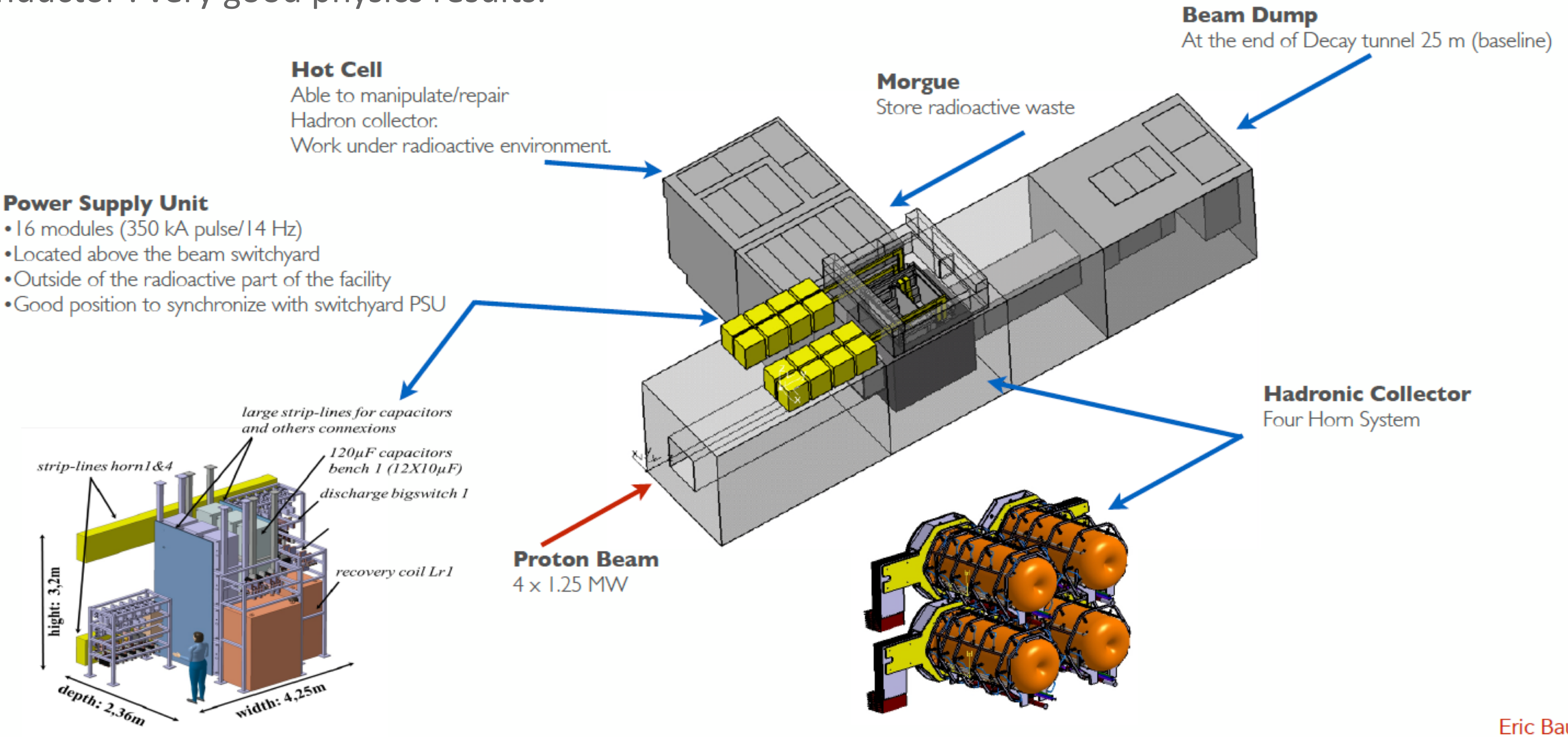


E. Bouquerel, IPHC Strasbourg

Target Design

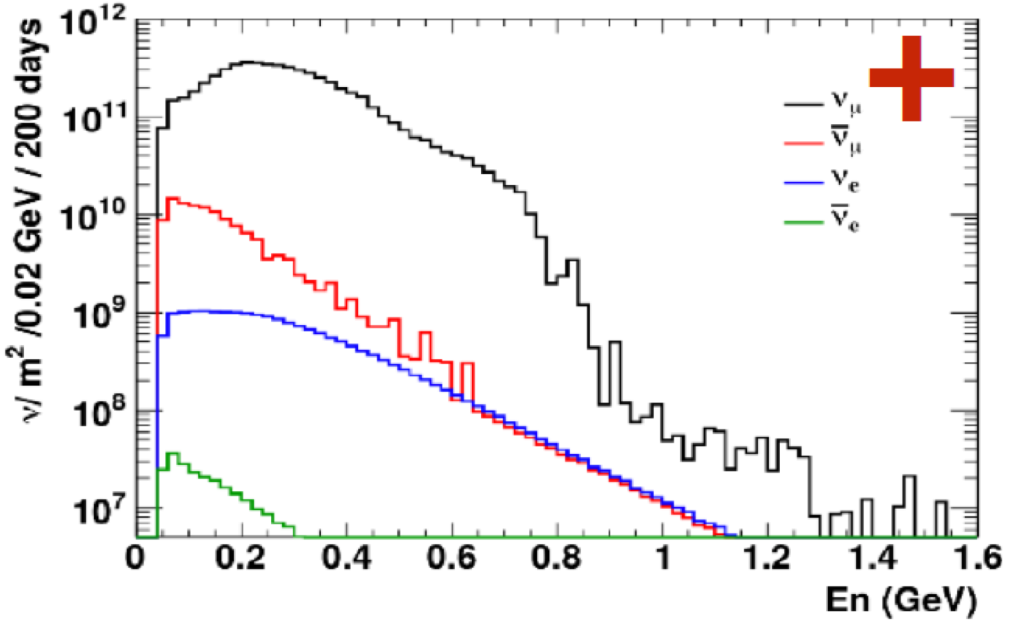
Packed Bed Target: Power 1.25 – 1.6 MW. Potential heat removal rates at the hundreds of kW level. Helium cooling (10 bars). Separated from the horn

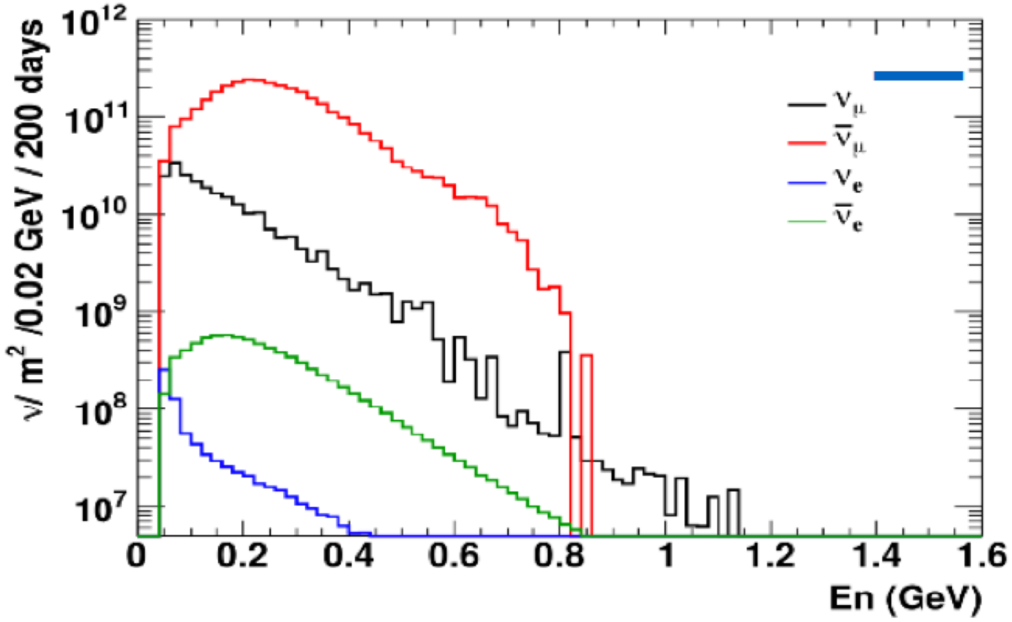
Focusing System: 4-horn+4 target system to accommodate the MW power scale. Packed bed target integrated into the inner conductor : very good physics results.



Eric Baussan

Expected Neutrino Flux





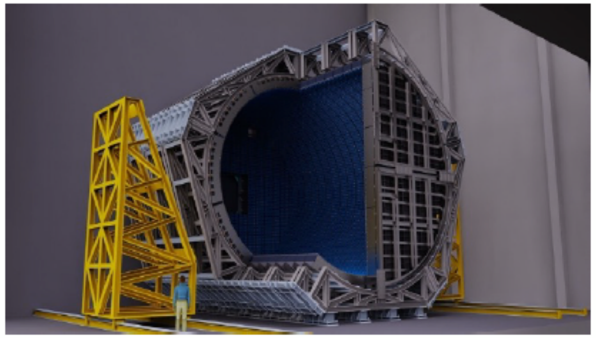
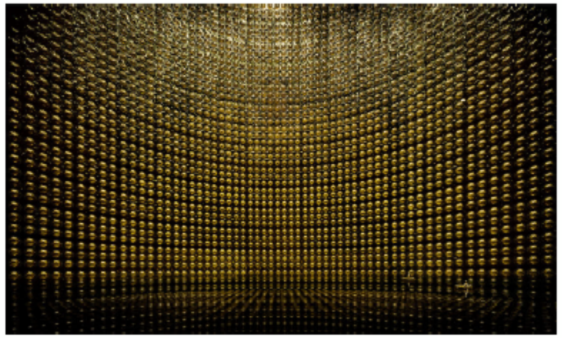
	Positive Polarity		Negative Polarity	
	N (1E10 1/m²)	%	N (1E10 1/m²)	%
Muon neutrino	583	98	23.9	6.55
Muon anti neutrino	12.8	2.1	340	93.2
Electron neutrino	1.93	0.3	0.08	0.02
Electron anti neutrino	0.03	0.01	0.78	0.21

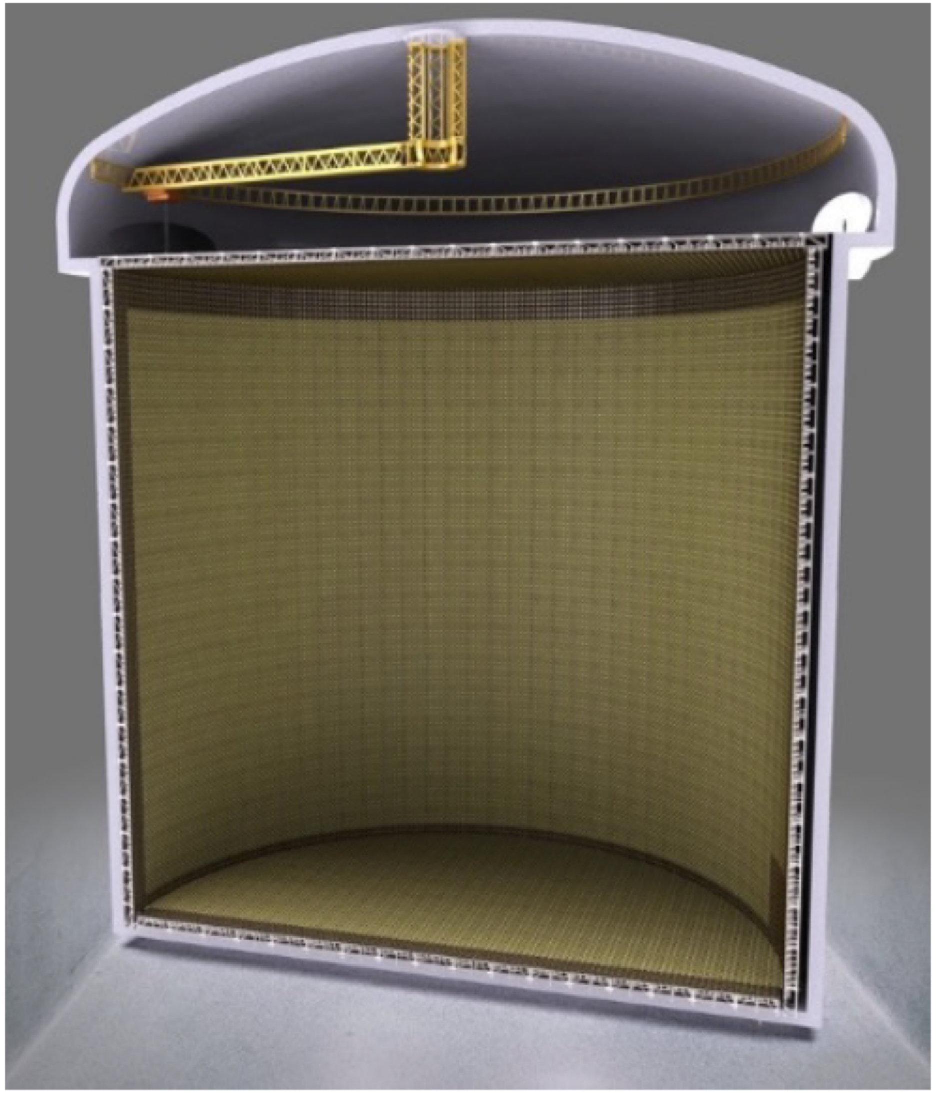
Eric Baussan

Detectors

Two water Cherenkov detectors

- Far detector (370 km from target)
  - – Pi x 372 x 74 m3 >0.5 Megaton of ultra pure water as the far detector . That is 10 times the volume of the super-Kamiokande.
  - – 540k m3 total fiducial volume
  - – 100k 20” PMTs gives 40% coverage
  - – 1500 meter deep underground
  - – To decrease the noise and background from cosmic radiation
- Near detector (250 m from target)
  - – Pi x 4.722 x 11 m3

Next Steps

Further important studies needed before start ESSnuSB construction.

• supplementary studies required for the present proposal (according to present WP conclusions),

• site specific civil underground engineering: at ESS-site and far detector site,

Preparation of the R&D phase,

• detailed studies of the safety and licensing requirements needed for the later approval by the authorities as well as how to take environmental protective measures into account

• elaborated radiation protection issues, material and waste optimization,

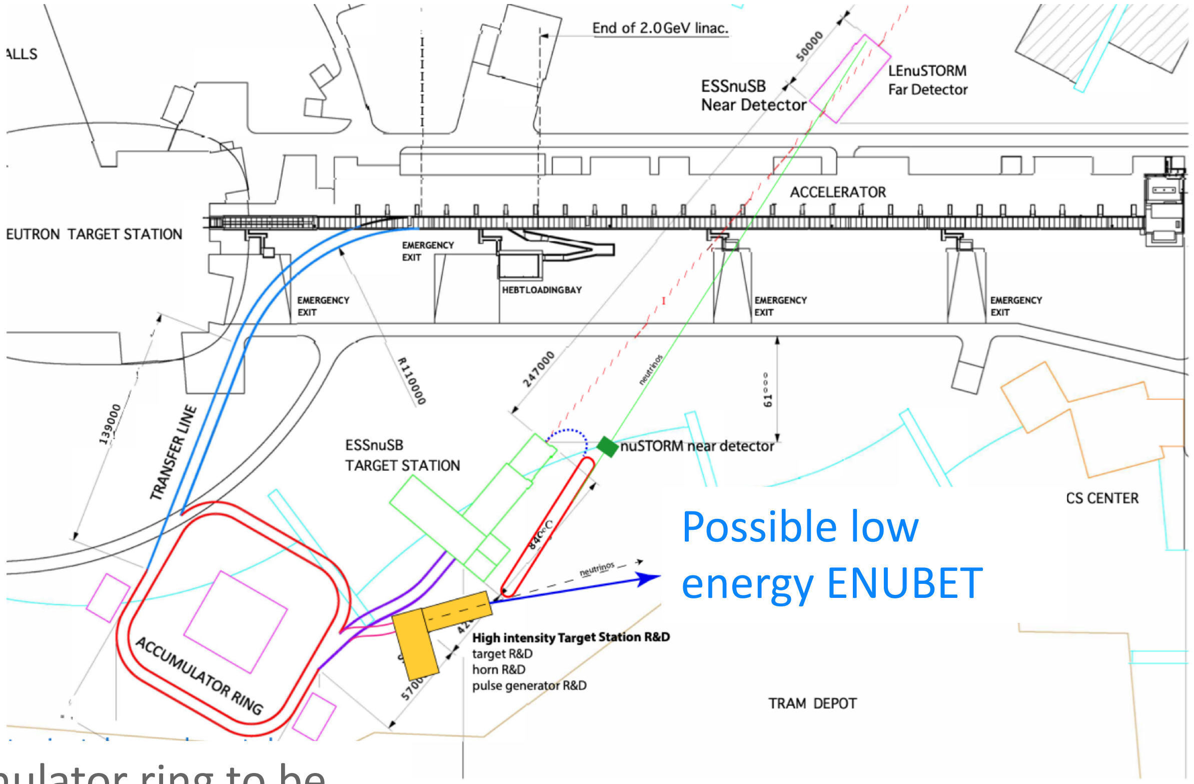
• optimized safety operations (construction and maintenance) including the near and far detectors.

• provide energy and material saving/reuse solutions for the ESSnuSB installations on the ESS site and the Far Detector.

Next Steps

ESS NEUTRINO SUPER BEAM

Proposed Scenario for the period 2022-25



Accumulator ring to be complemented with a NuSTORM ring

Low Energy nu STORM
- ~0.5 GeV muons
- sterile neutrinos
- cross-section measurements

ENUBET
- cross-section measurements

Further studies on:
- Civil engeneering
- Target
- Accelerator improvements (fine tuning)

Final Goal:
- Multi purpose facility with great potential for material and particle physics studies!

ESS NEUTRINO SUPER BEAM

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Thank you!
Questions?