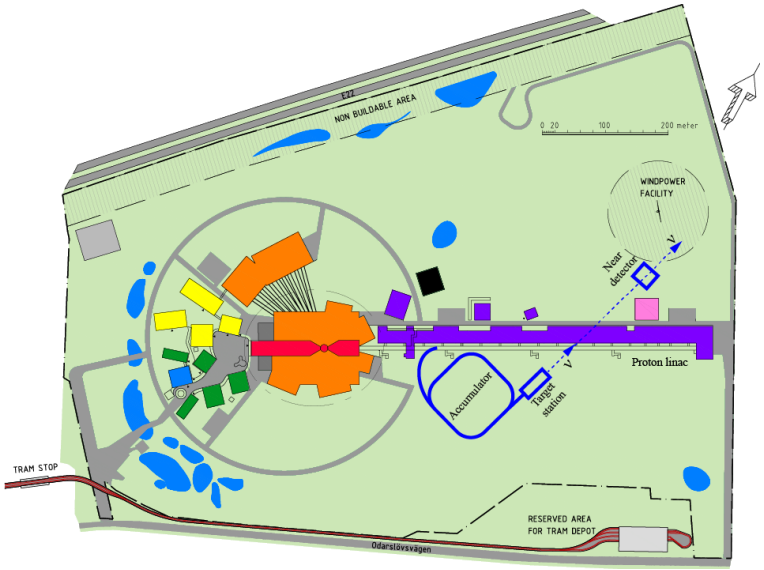
High Intensity Frontier Physics with ESS

Photo 8 October 2020

Tord Ekelof
Uppsala University

The European Spallation Source neutrino Super Beam ESSnuSB Design Study

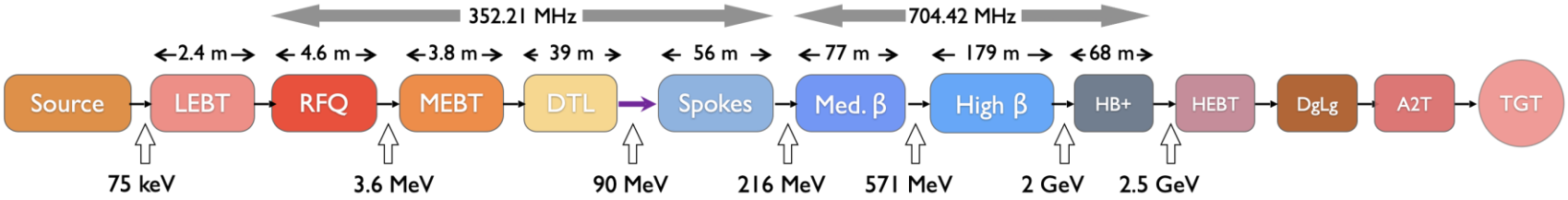
Midterm report issued spring 2020:
"Report on the results obtained during the second year at midterm of the ESSnuSB Feasibility Study for Employing the Uniquely Powerful ESS Linear Accelerator to generate an Intense Neutrino Beam for Leptonic CP Violation Discovery and Measurements"



Report available at
https://essnusb.eu/DocDB/public/ShowDocument?docid=706

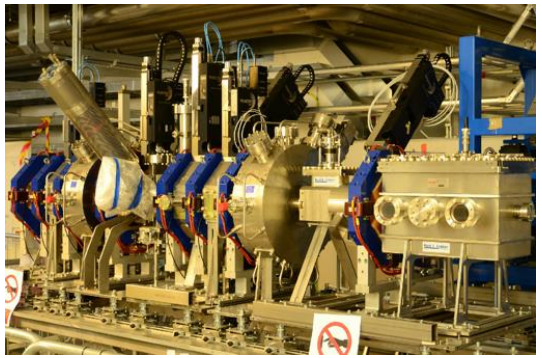
A 6.5 minutes ESSnuSB video film available **at** https://youtu.be/PwzNzLQh-Dw

The ESS linac today



ESS 8 October 2020

RFQ



MEBT

The ion source and the LEBT (Low Energy Beam Transport) , the RFQ (Radio Frequency Quadrupole) and the MEBT (Medium Energy Beam Transport) have now been installed in the ESS accelerator tunnel and are under commissioning

ESS Timetable

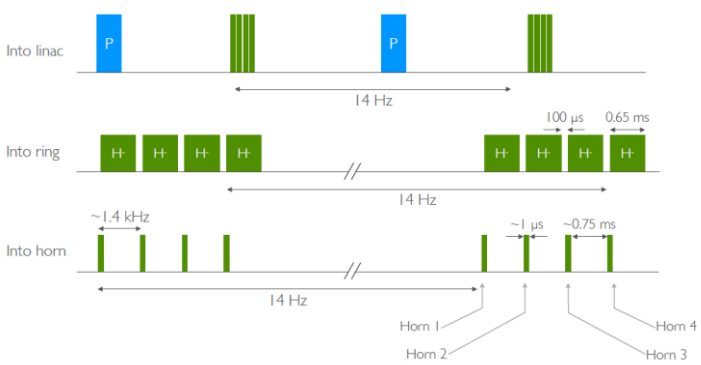
DTL

First spoke CM 18 Oct 2020

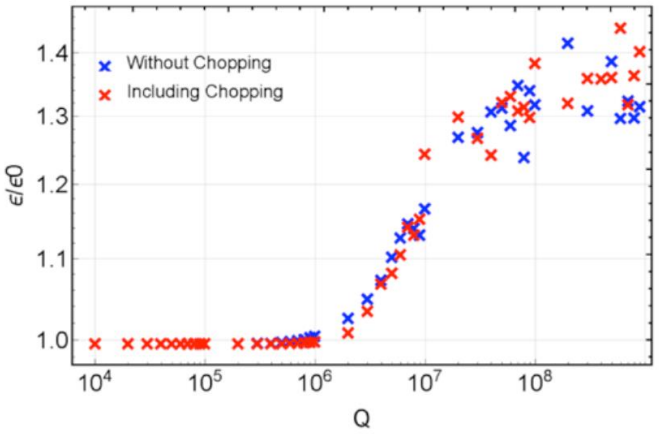
Spoke CM proto in FREIA

- The DTL (Drift Tube Linac) is being assembled in a mounting hall at ESS.
- The first Spoke Cavity CM (Cryo Module) arrived from IJCLAb Orsay on 18 October and is currently being tested at the FREIA Laboratory in Uppsala.
- The first Elliptical CM has arrived at ESS and is being prepared for tests at ESS
- First beam at reduced energy and power in 2023.
- Full power 5 MW and energy 2 GeV in 2025 if sufficient funding will be made available

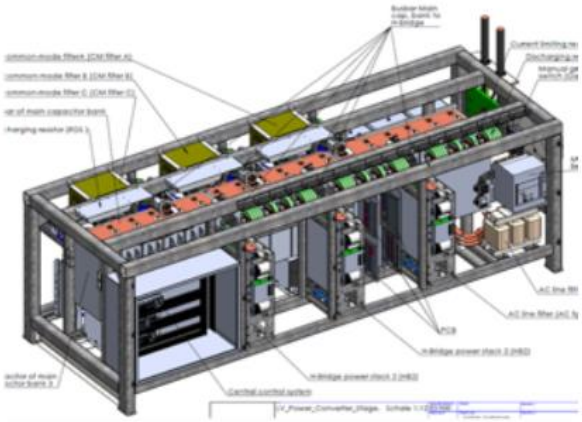
The ESS linac upgrade to 10 MW



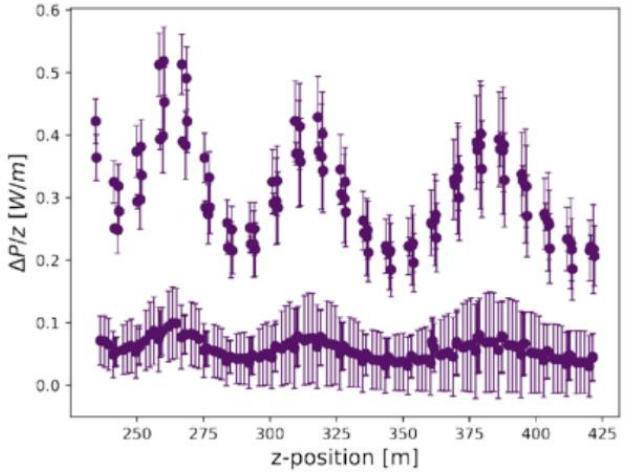
Pulse scheme



Result of chopping

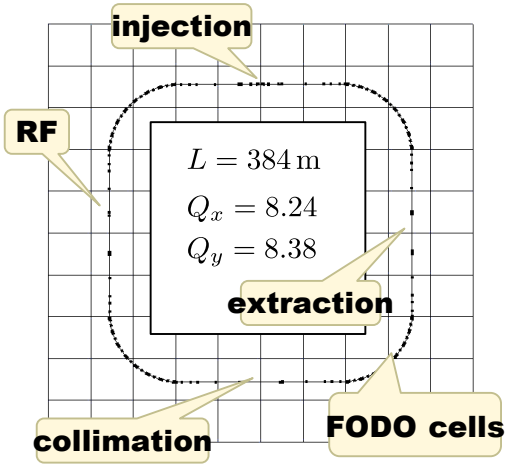


Modulator capacitor upgrade

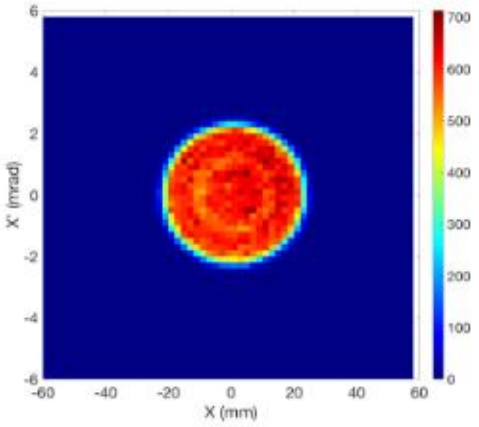


Intra Beam Stripping

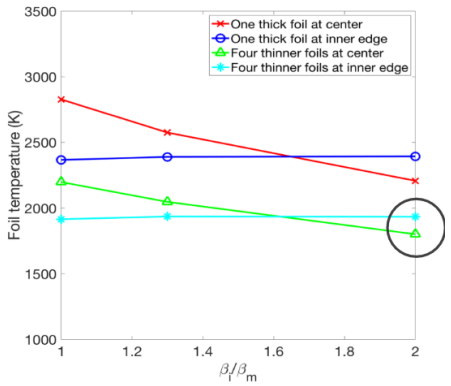
Accumulator optimization



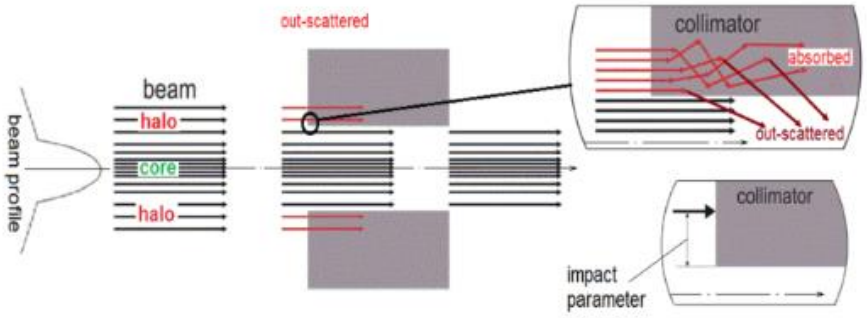
Accumulator lay-out



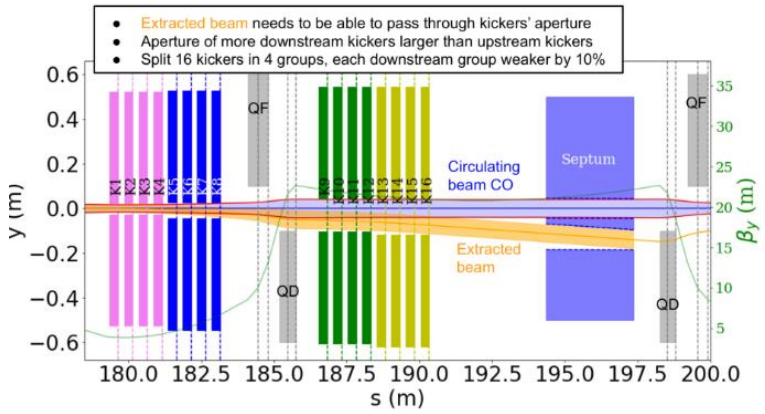
Beam injection painting



Optimizing stripping foil temperature

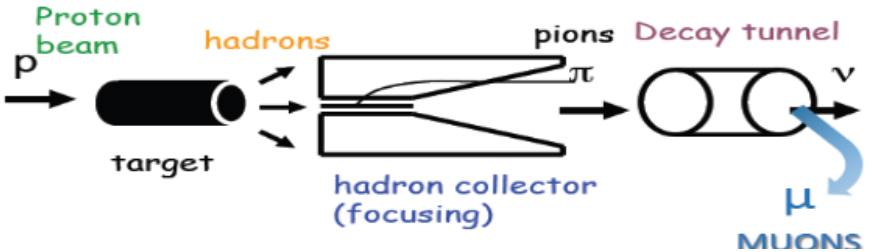


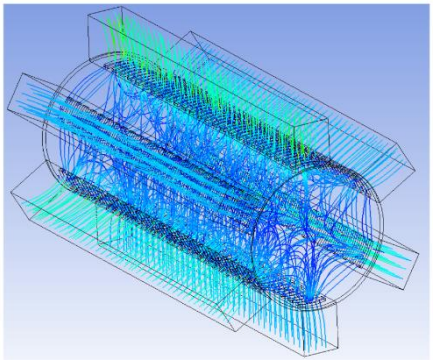
Two-stage collimation system



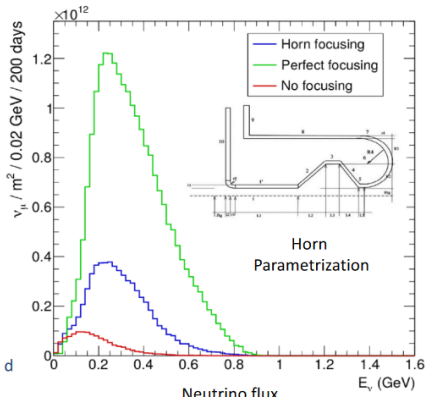
Beam extraction

The target station studies

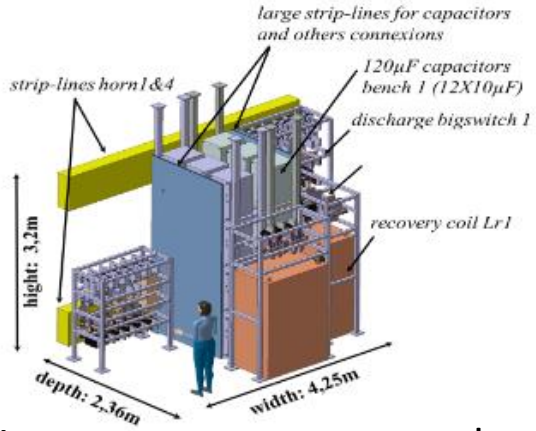




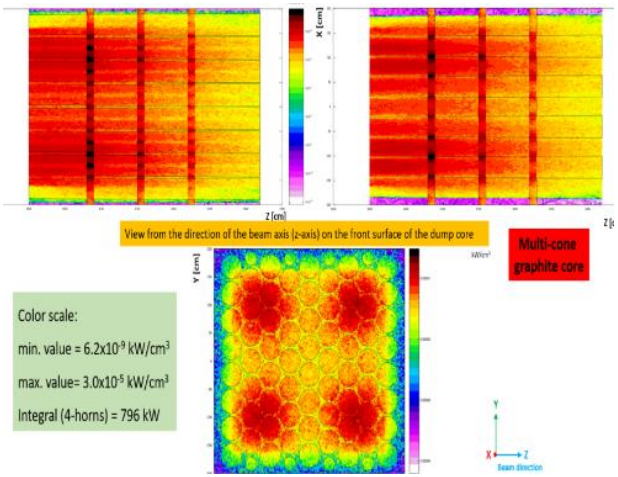
Ti Spheres Packed Bed Target
Helium cooling



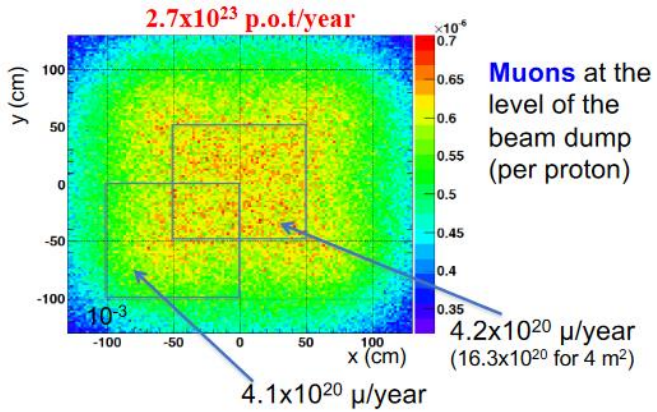
Focusing horn optimization



Horn current power supply optimization

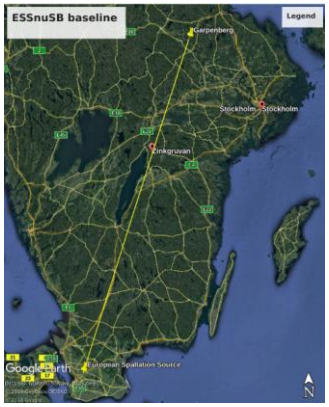


Segmented beam dump

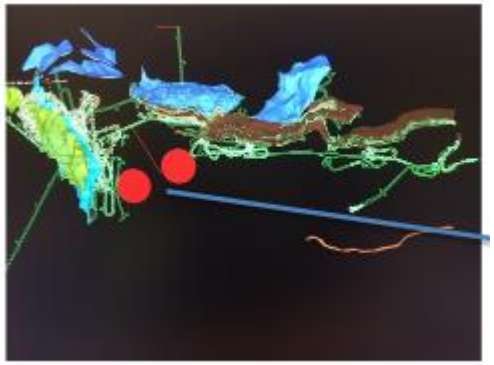


Muon flux at end of decay tunnel

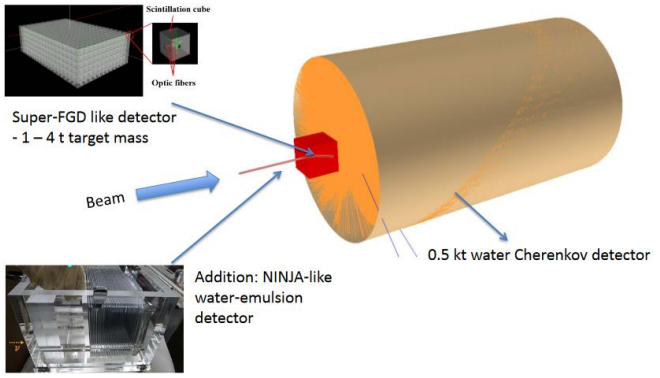
The near and far detectors



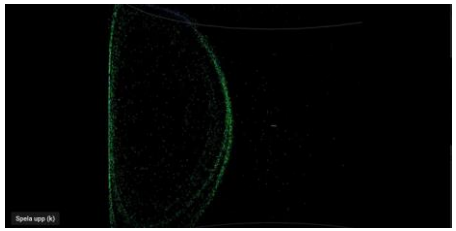
Two far detector locations



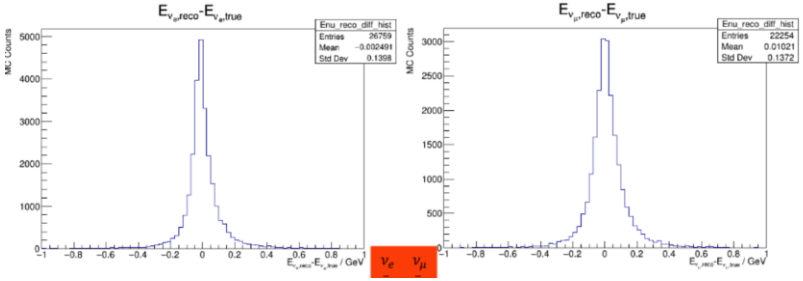
The far detector location at Zinkgruvan



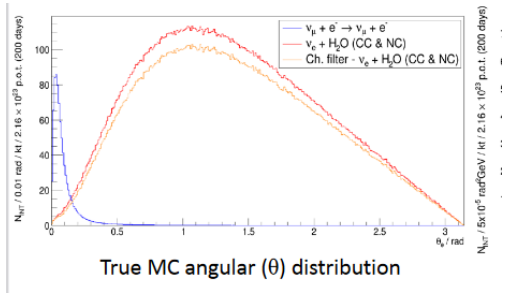
The components and lay-out of the near detector



A muon ring in the far detector



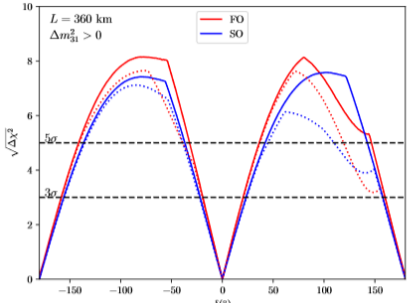
Reconstructed ν energy minus true ν energy for ν_e (left) and ν_μ (right)



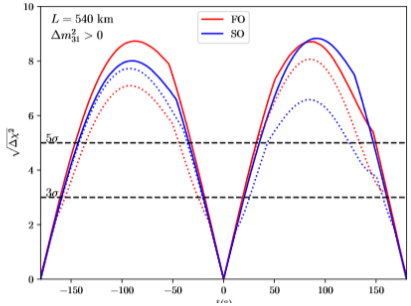
Angular distribution for scattering of ν_μ on electrons (left) and ν_e on H_2O (right)

ESSnuSB physics performance

Zinkgruvan

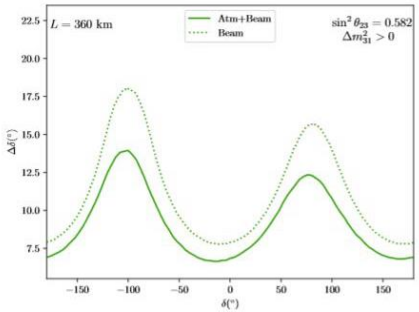


Garpenberg

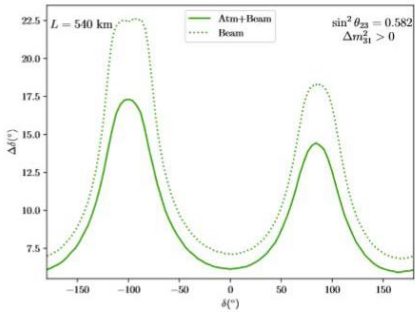


Upper: CPV discovery potential

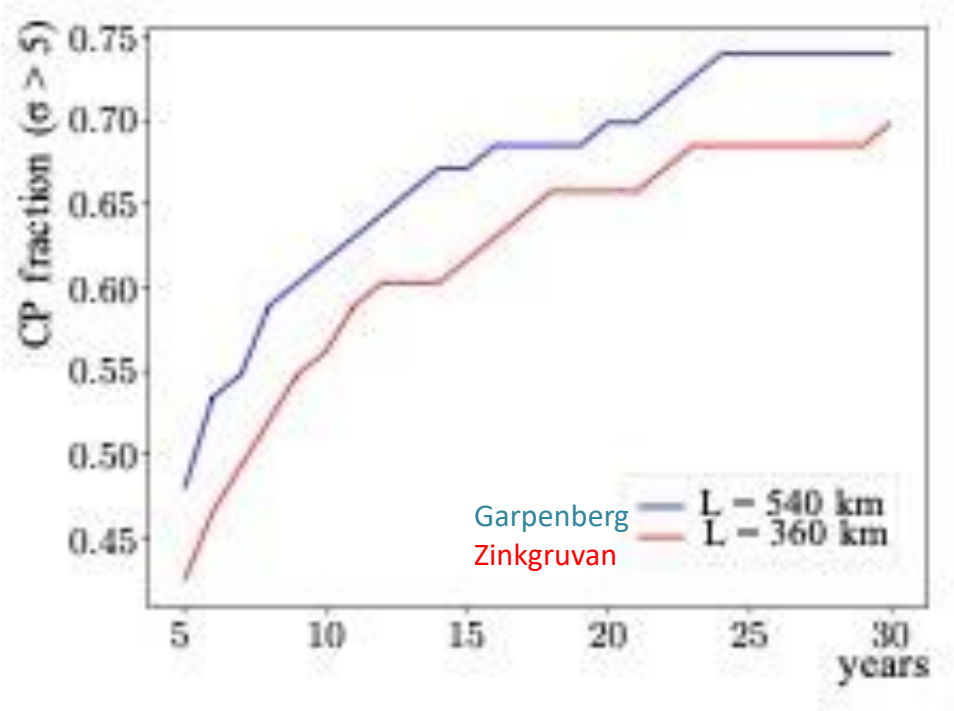
Zinkgruvan



Garpenberg



Lower: CP angular resolution



CPV discovery potential vs exposure time

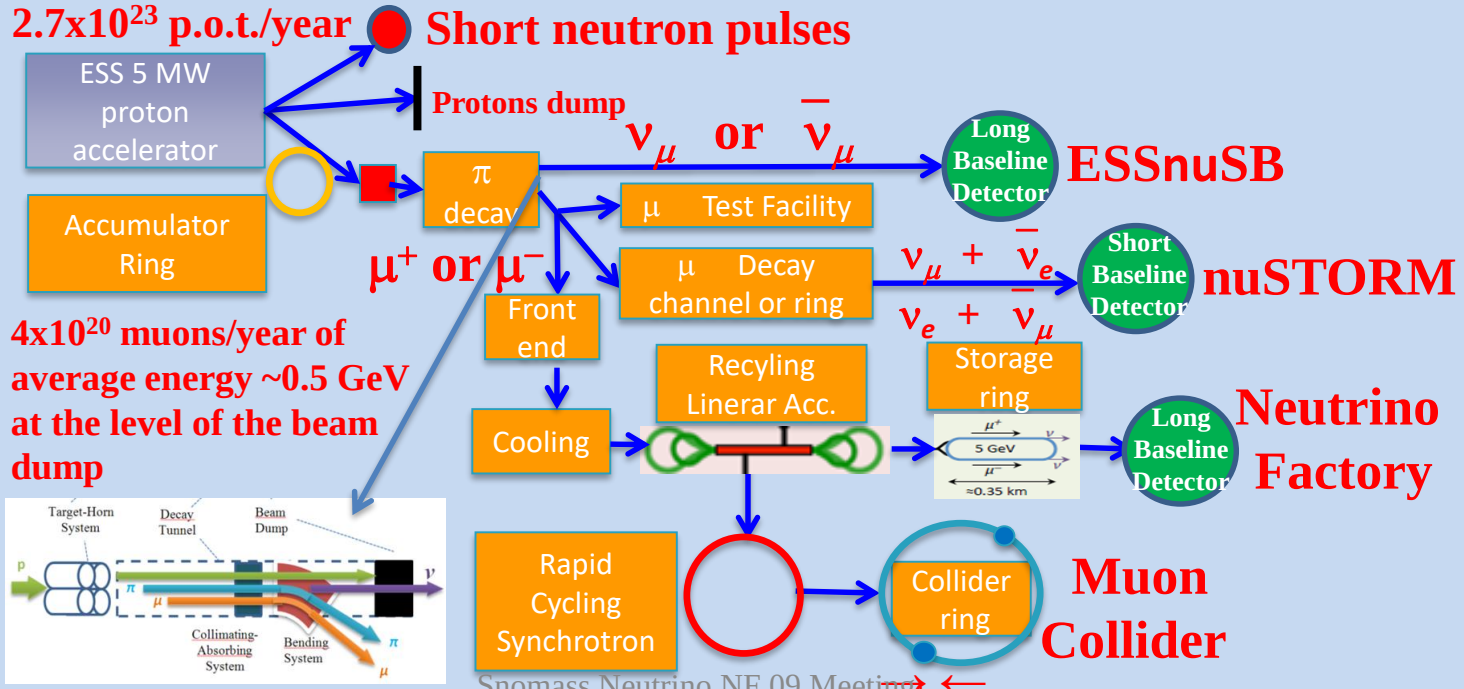
Both plots above: Dashed beam data only, full line with atmospheric data

Prospects for Intensity Frontier Particle Physics with Compressed Pulses from the ESS Linac

High Intensity Frontier Initiative HIFI

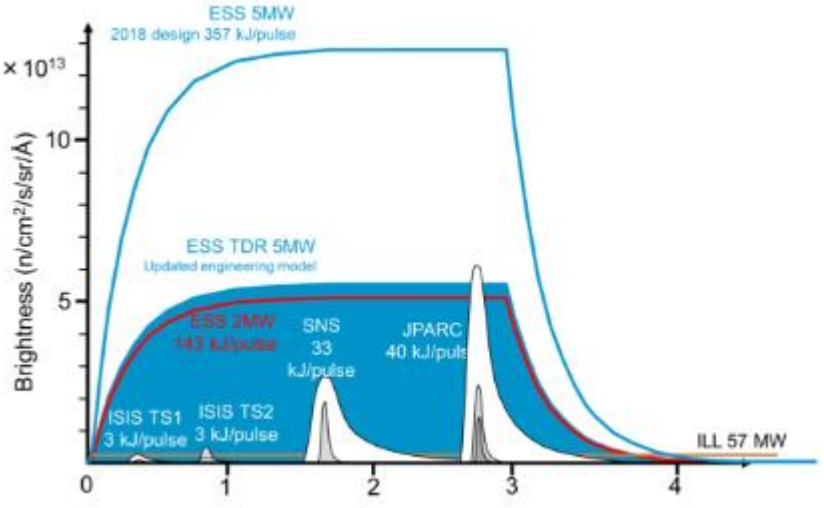
Open workshop at Uppsala University
2-3 March 2020

Program and registration at: https://indico.cern.ch/event/849674/

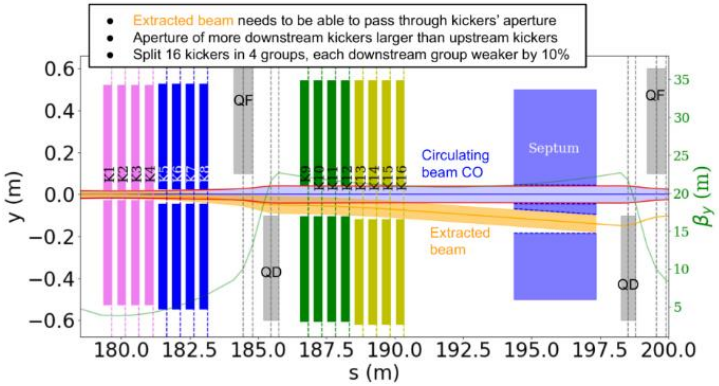


The participants in the HIFI Uppsala Workshop 2-3 March 2020

Short HIFI spallation neutron pulses



ESS will have an order of magnitude higher spallation neutron flux per pulse and much longer pulses (3 ms) than other sources have (typically 1 µs)

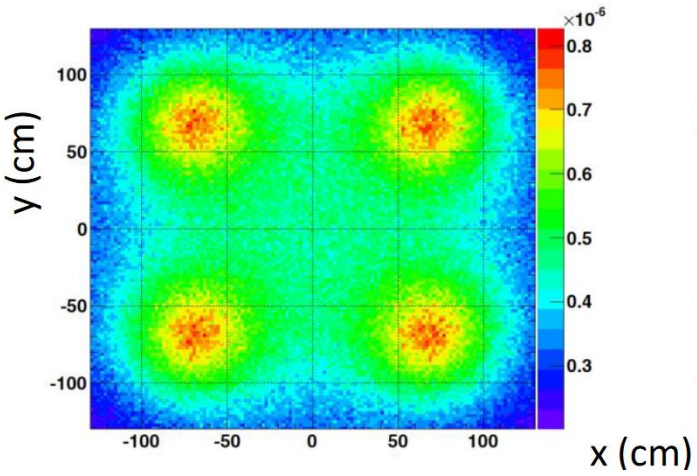


Fast extraction from the ESSnuSB accumulator produces 1.3 µs neutron pulses pules

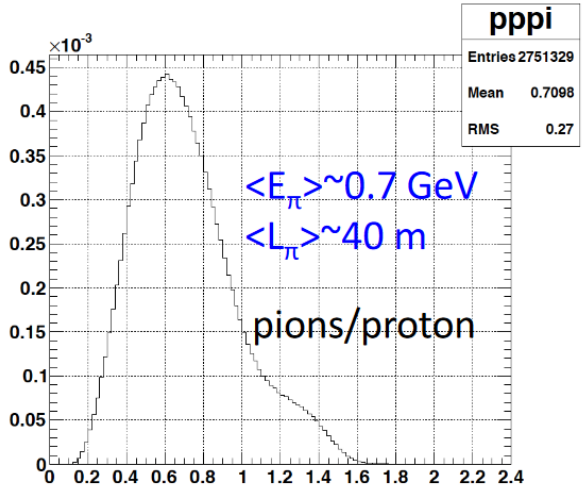
Equipping the accumulator with slow extraction to produce 50 µs pulses, which is the approximate moderation time of the neutrons, a much higher instantaneous neutron flux and better pulse timing could be achieved, adding further to the ESS' already leading features as neutron source for material sciences.

HIFI Pions at the level of the ESSnuSB beam dump

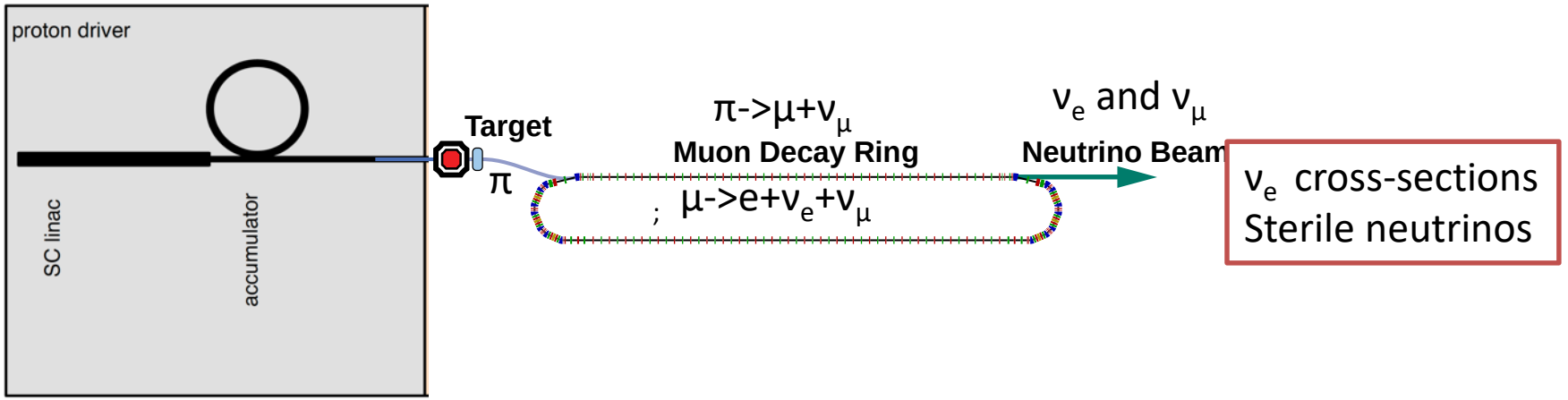
ESS linac 2.7x10^{23} p.o.t/year



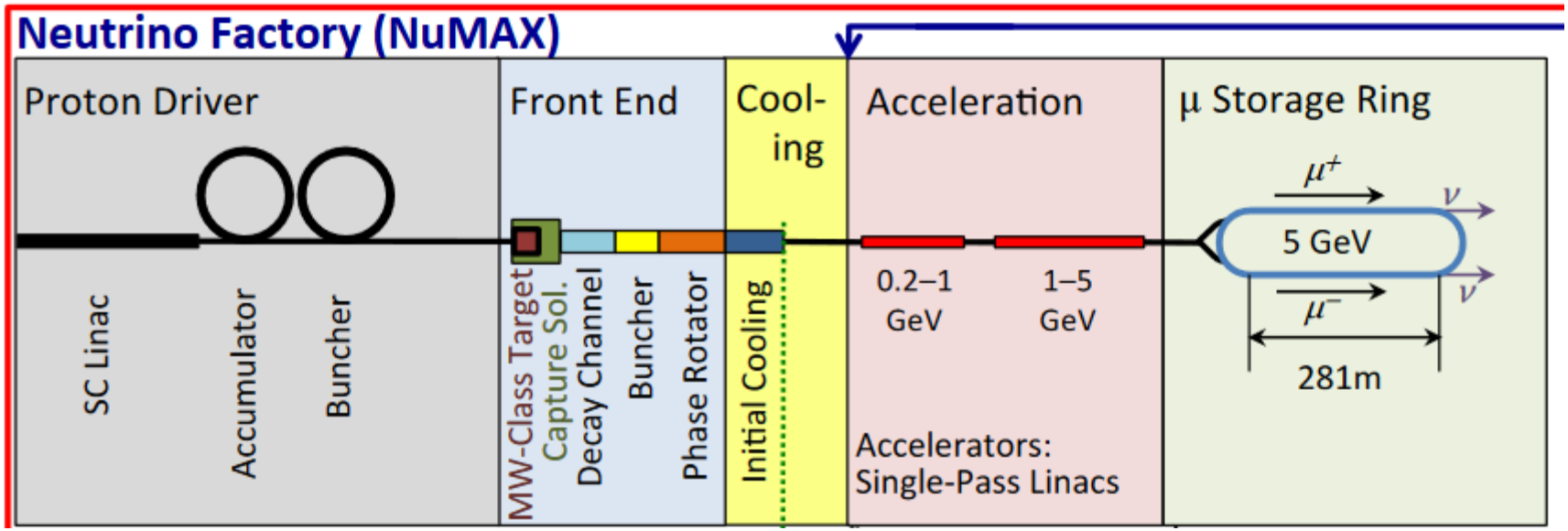
Pions at the level of the ESSnuSB beam dump, 56% per proton, i.e.1.5x10^{23} π/year

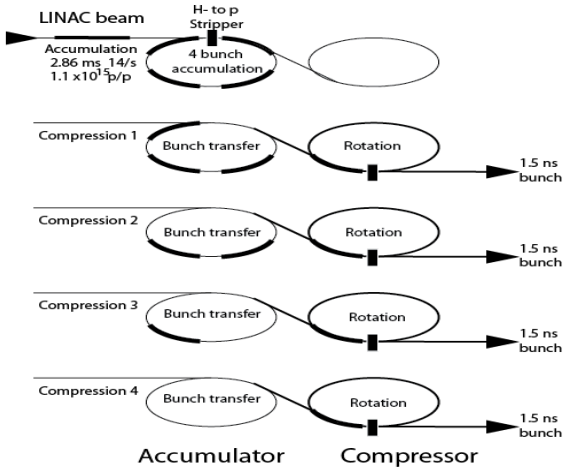


nuSTORM

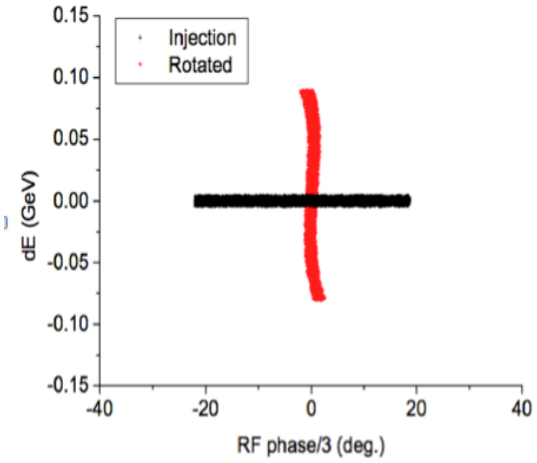


HIFI Neutrino Factory





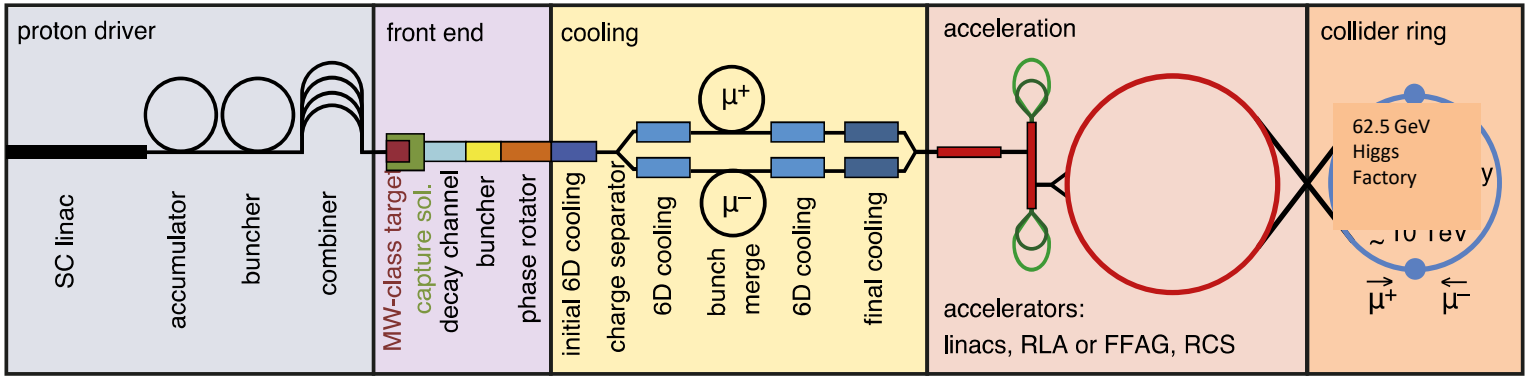
Accumulation and bunching

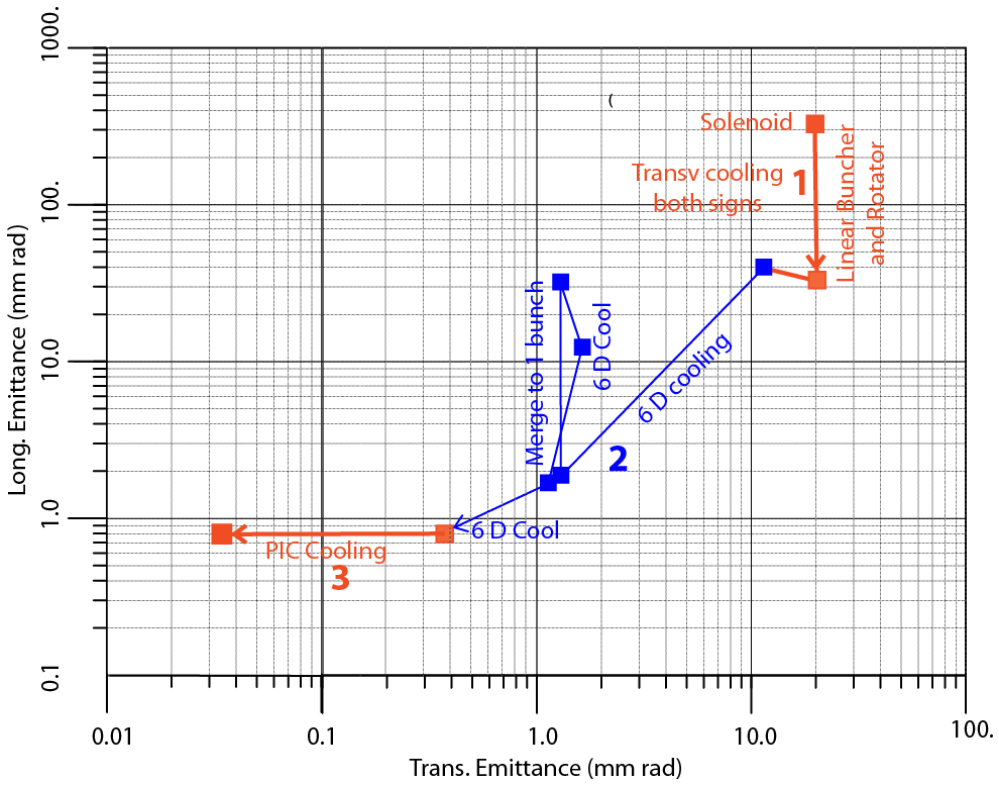


Phase rotation

Then cooling, acceleration and storage in a μ decy ring

A HIFI Muon Collider Higgs Factory at ESS





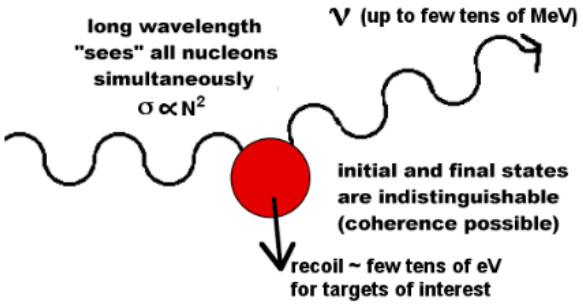
Muon cooling in 3 steps:

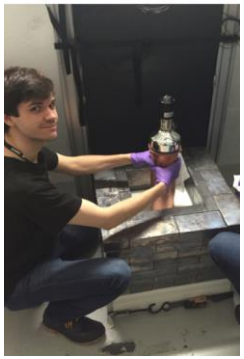
1. Linear transverse cooling
2. 6D cooling
3. Parametric Resonance Cooling

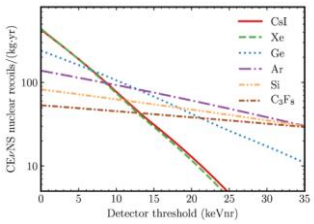
Then acceleration to

62.5 GeV and collisions

HIFI Coherent ν-N scattering

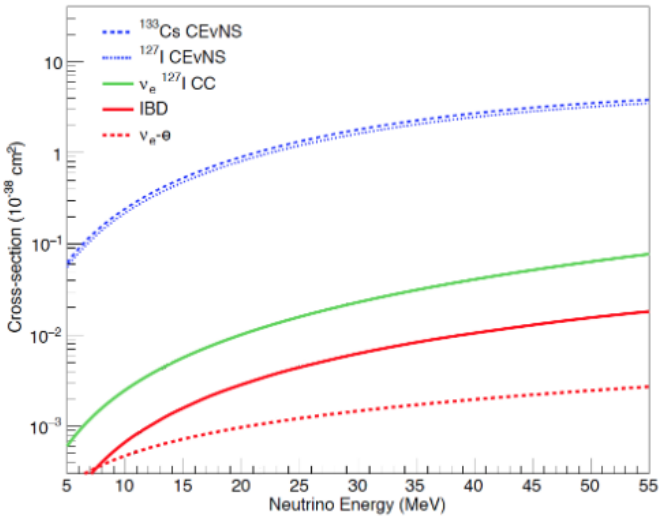






0-20 kg

~10 keV detector threshold



Huge cross-sections

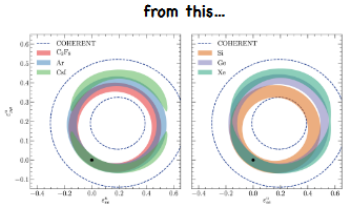
Taking it to the next level: ESSνSB

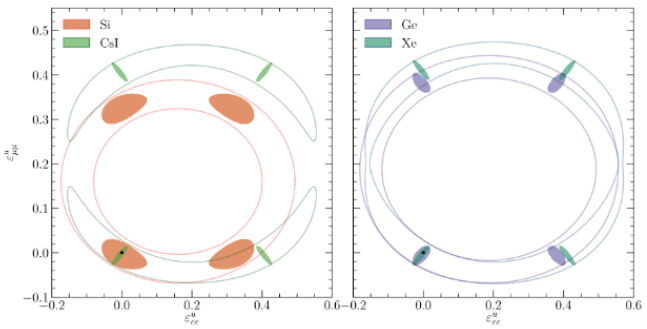
ESSνSB pulse compression brings:

- **background drops with duty factor by x70**
- **timing information (prompt vs. delayed ν's)**

Talks by Dracos & Gålnander @
https://indico.cern.ch/event/849674

from this…



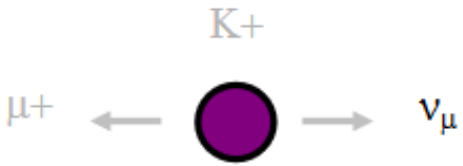


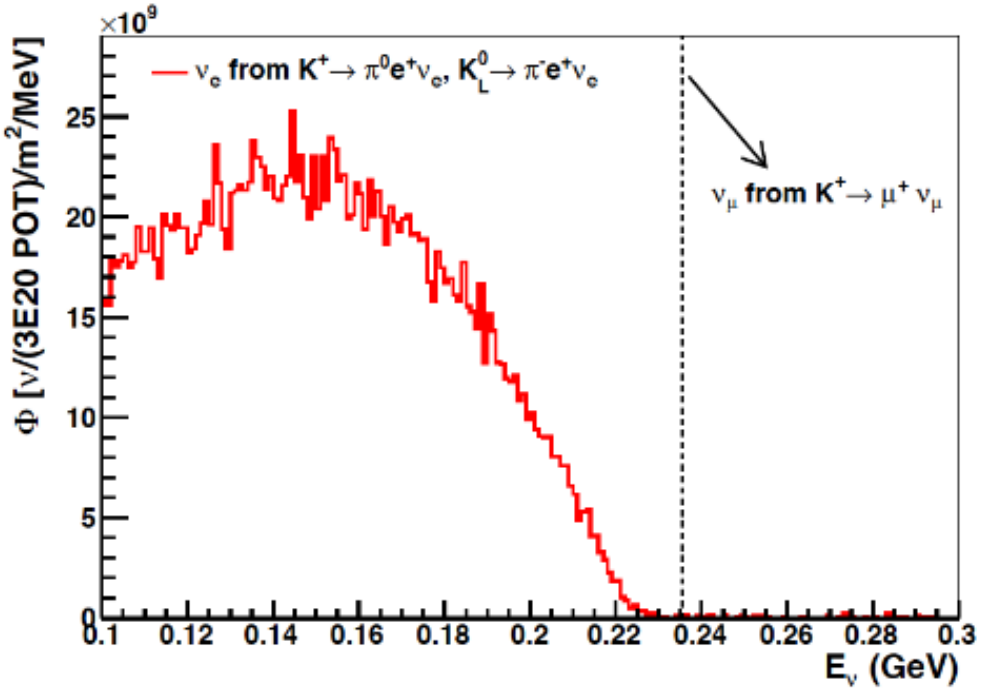
to this…

(improvement not limited to NSI, timing opens up other physics possibilities)

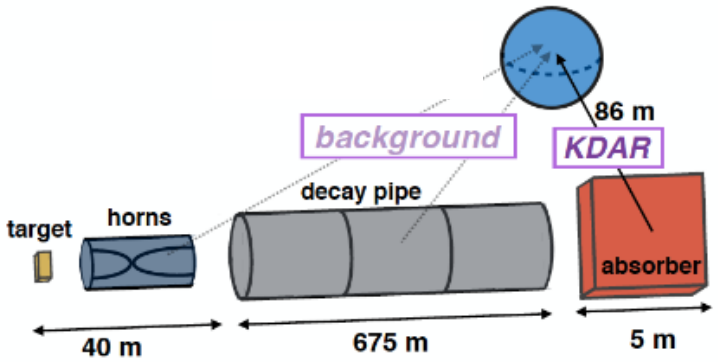
Preliminary study from
I. Esteban, C. Gonzalez-Garcia,
P. Coloma)

HIFI Kaon- decay-at-rest KDAR





K-pipe



236 kE ν_μ monoenergetic beam from the ESSnuSB beam dump that can be used to search for ν_μ oscillations to sterile ν

The interested community active in the ESSnuSB design study and the other HIFI projects is composed of more than 70 physicists affiliated to the following 24 institutions:

Centre National de la Recherche Scientific at IPHC (Strasbourg) and at IJCLab (Orsay), France
Cukurova University, Adana, Turkey
Demokritos Center, Athens, Greece
Donostia International Physics Center, San Sebastian, Spain
European Organisation for Nuclear Research, Geneva, Switzerland
European Spallation Source, Lund, Sweden
Gran Sasso Science Institute, L'Aquila, Italy
Imperial College, London, UK
Institute of High Energy Physics, Beijing, China
Istituto Nazionale di Fisica Nucleare (INFN) at Bari, at Milano and at Padova, Italy
Lund University, Sweden
Massachusetts Institute of Technology, USA
University of Michigan, USA
Royal Institute of Technology, Stockholm, Sweden,
Rudjer Boskovic Institute, Zagreb, Croatia
Sofia University St. Kliment Ohridski, Sofia, Bulgaria
Universidad Autonoma de Madrid, Spain
University of Durham, UK
University of Hamburg, Germany
University of Science and Technology, Krakow, Poland
University of Oslo, Norway
University of Texas, Arlington, USA
University of Thessaloniki, Greece
Uppsala University, Sweden

This enlarged collaboration intends to apply to Horizon Europe for the financing of a HIFI at ESS design study 2022-2025, which shall result in a Technical Design Report for ESSnuSB and a conceptual Design Report for the other projects by 2025.

EU funding opportunities from 2021

Destination 1.1 RI Concept Development (similar to the Horizon 2020 Design Studies):

Includes: major upgrades of existing infrastructures: if the end result is significantly transformative/equivalent to a new infrastructure concept.
How much? Ca 3 MEUR for a 4 years Design study
Next dead-line: 24 Mar 2022

ERC Synergy Grants

Who can apply?
A group of two to maximum four Principal Investigators (PIs) working together and bringing different skills and resources to tackle ambitious research problems. Proposals will be evaluated on the sole criterion of scientific excellence and intrinsic synergetic effect.
How much? 10-14 MEUR
Next dead-line: In November 2022

Conclusions

- The ESSnuSB Design Study is well advanced - it has produced a midterm report and will deliver a Conceptual Design Report (CDR) by end 2021, demonstrating the feasibility and superior performance of the ESS high intensity neutrino beam.

- An initiative has been taken to enlarge the scope of the Design Study to include several High Intensity Frontier projects based on the ESS linac and the ESSnuSB accumulator like nuSTORM, Neutrino Factory, Muon Collider, Coherent Neutrino Scattering, Decay at Rest and High Intensity Short Spallation Neutron pulses.

- The enlarged collaboration intends to apply for Horizon Europe support for a study of such an extended design study 2022-2025, resulting in a Technical Design Report (TDR) for ESSnuSB and a conceptual Design Report for the other projects by 2025.

.