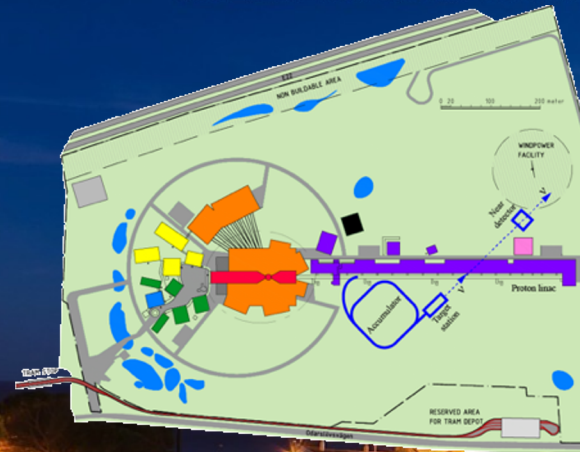


Status of the ESSvSB Design Study and plans for its continuation

NuFact 20|21

The 22nd International Workshop on neutrinos from accelerators

SEPT
6-11, 2021
Cagliari, Italy



Marcos Dracos
IPHC-Strasbourg/UNISTRA/IN2P3

The European Consortium working on the ESSvSB project

□

- COST Action EuroNuNet (CA15139): ended March 2020

- <https://euronunet.in2p3.fr>

- video for scientists:

- <https://www.youtube.com/watch?v=PwzNzLQh-Dw>



ESSnuSB Design Study Project



- EU-H2020 Design Study ESSvSB: on going up to March 2021 (3 months extension due to COVID19)

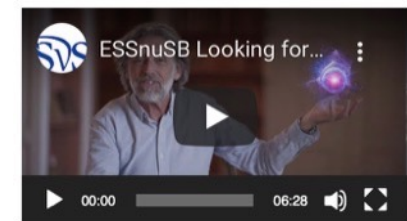
- <https://essnusb.eu>

- video for general public:

- <https://www.youtube.com/watch?v=qAnvft0nAlg>

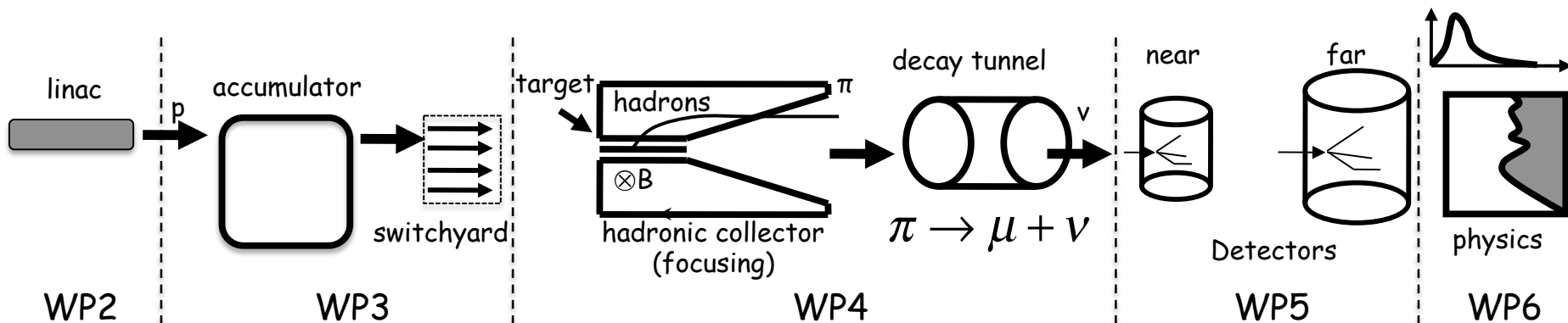
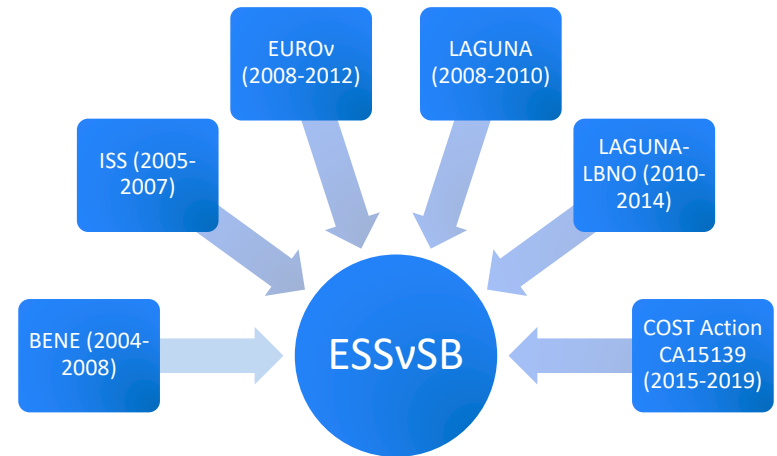


ESSnuSB looking for the answer.



The H2020 ESSvSB Design Study

- A H2020 EU Design Study has been submitted March 2017 (Call INFRADEV-01-2017)
- **Title of Proposal:** Discovery and measurement of leptonic CP violation using an intensive neutrino Super Beam generated with the exceptionally powerful ESS linear accelerator.
- **Duration:** 4 years
- **Total cost:** 4.7 M€
- **EU funding received:** 3 M€
- 15 participating institutions from 11 European countries including CERN and ESS
- 6 Work Packages



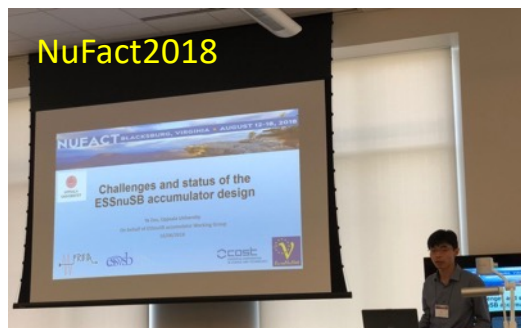
Aim: add a neutrino facility on top of the ESS neutron one

- The neutron program must not be affected and if possible synergetic modifications.
- Linac modifications: double the rate (14 Hz \rightarrow 28 Hz), from 4% duty cycle to 8%, add H⁻ source.
- Accumulator to compress to 1.3 μ s the 2.86 ms proton pulses.
- Target station.
- Underground near and far detectors.
- Evaluation of physics performance

- **mandate well accomplished**
- **A CDR including cost estimate will be published end 2021**



Many dissemination activities

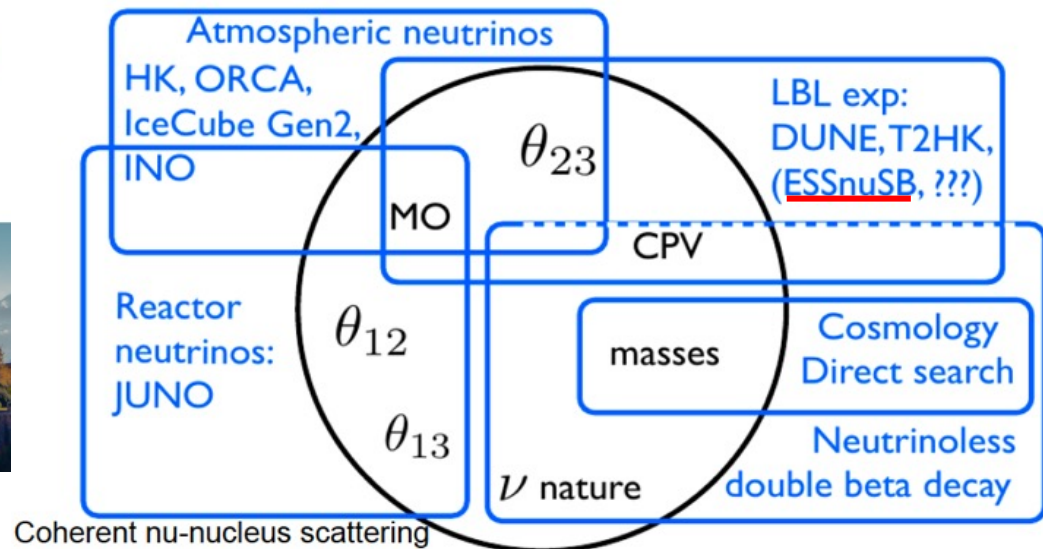


European Particle Physics Strategy

CERN Council Open Symposium on the Update of

European Strategy for Particle Physics

13-16 May 2019 - Granada, Spain



Coherent nu-nucleus scattering

S. Pascali Granada 2019

The European Spallation Source neutrino Super Beam ESSvSB

input 98

Abstract

The European Spallation Source linear proton accelerator will have a uniquely high beam power of 5 MW to be used for spallation neutron production. The beam power can be raised to 10 MW by increasing the accelerator duty cycle from 4% to 8% and the additional 5 MW used to generate a uniquely intense neutrino Super Beam ESSvSB for measurement of leptonic CP violation. ESSvSB is complementary to other proposed Super Beam experiments by the fact that the resulting high neutrino-beam intensity makes it possible to locate the large water Cherenkov neutrino detector that will be used, at the second neutrino oscillation maximum, making the performance of ESSvSB for leptonic CP violation precision measurements highly competitive.

Contact persons

Tord Ekelöf Tord.Ekelof@physics.uu.se and Marcos Dracos marcos.dracos@in2p3.fr

"The design studies for next-generation long-baseline neutrino facilities should continue."

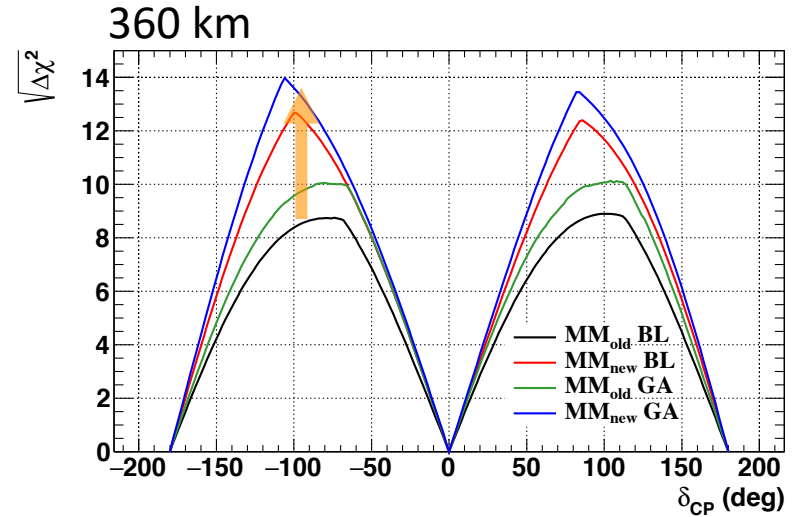
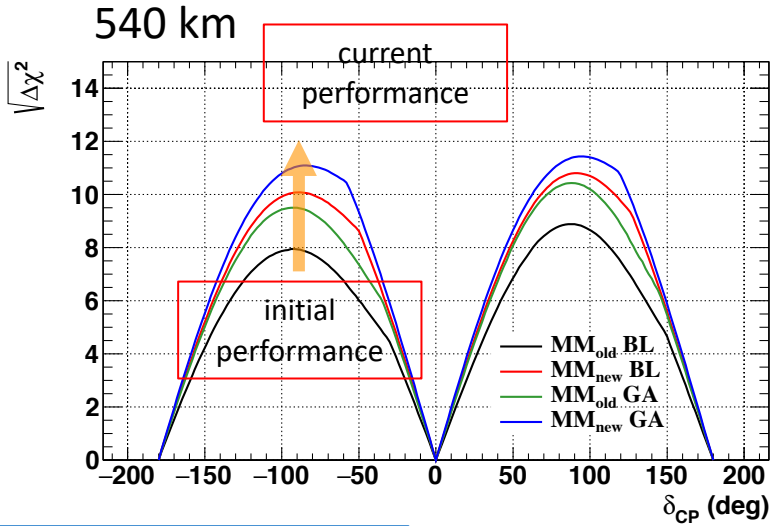
from deliberation document

Important progress made

ESSnuSB physics potential significantly improved



Decisive physics performance improvements



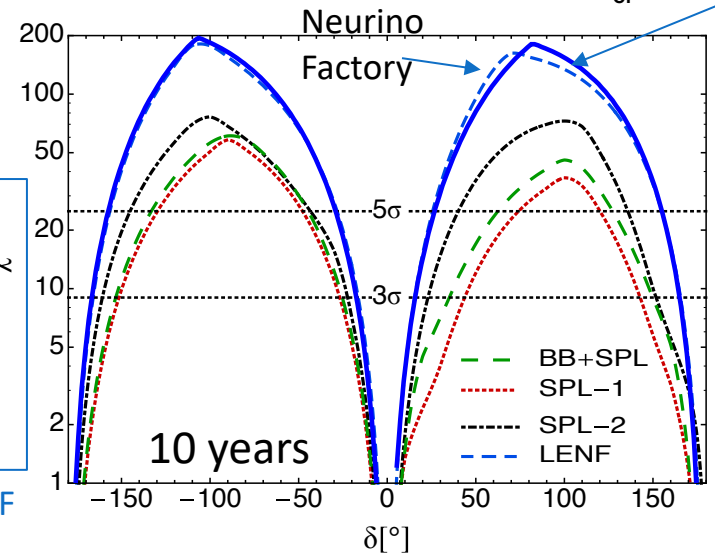
ESSnuSB

- $\theta_{12} = 33.44^\circ$
- $\theta_{13} = 8.57^\circ$
- $\theta_{23} = 49.2^\circ$
- $\Delta m_{21}^2 = 7.42e-5$
- $\Delta m_{31}^2 = +2.517e-3$
- 2nd osc. max.
- 507 ktons far detector
- **contribution of atm. neutrinos still to be included**

EUROnu

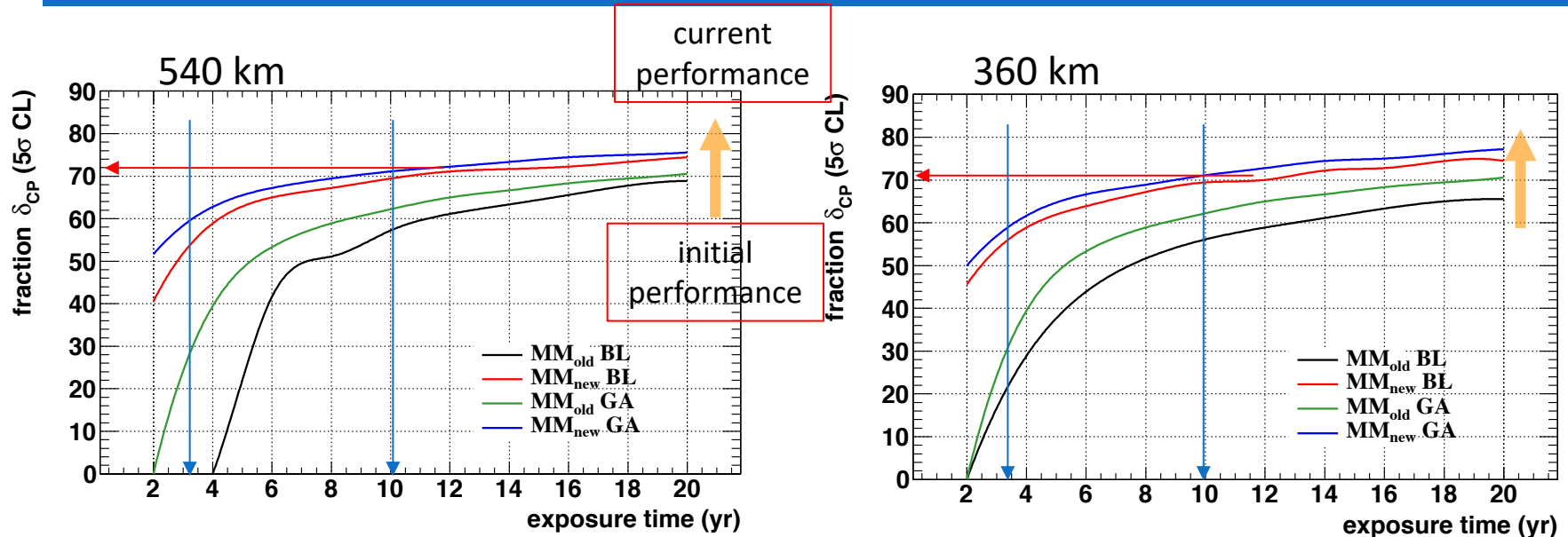
- $\theta_{12} = 33.2^\circ$
- $\theta_{13} = 9.2^\circ$
- $\theta_{23} = 45^\circ$
- $\Delta m_{21}^2 = 7.64e-5$
- $\Delta m_{31}^2 = +2.45e-3$
- 1st osc. max.

best version of NF



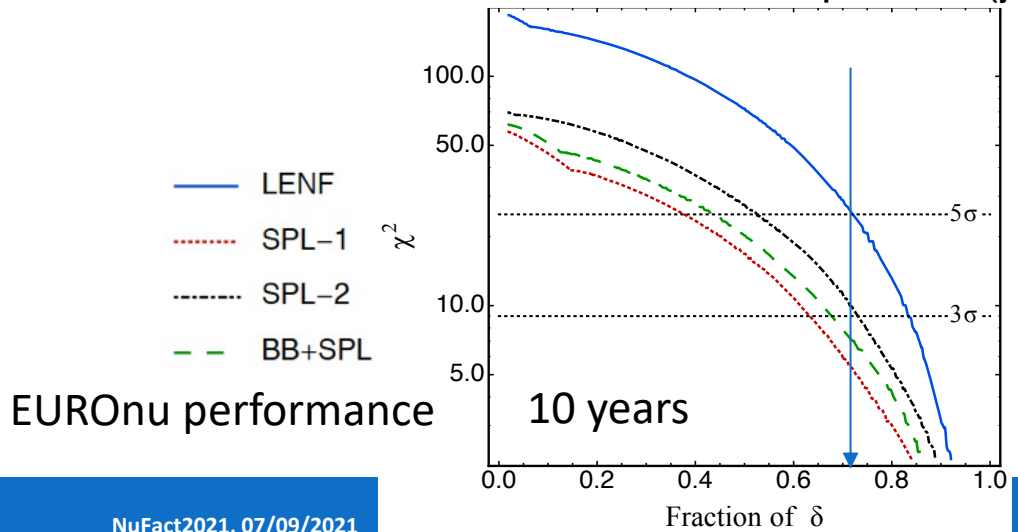
ESSnuSB

Decisive physics performance improvements



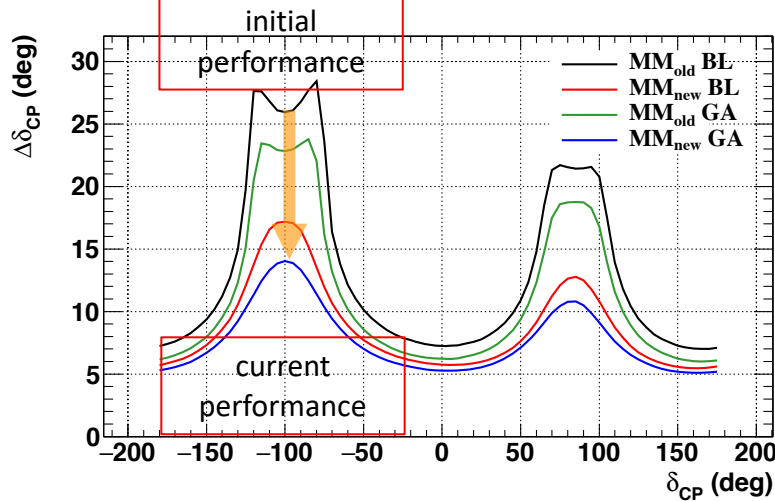
~72% after 10 years

discovery potential at the level of the Neutrino Factory!

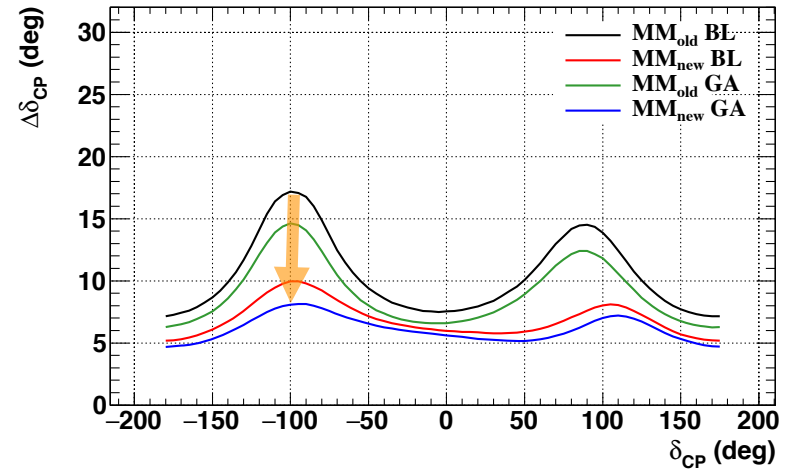


Decisive physics performance improvements

540 km



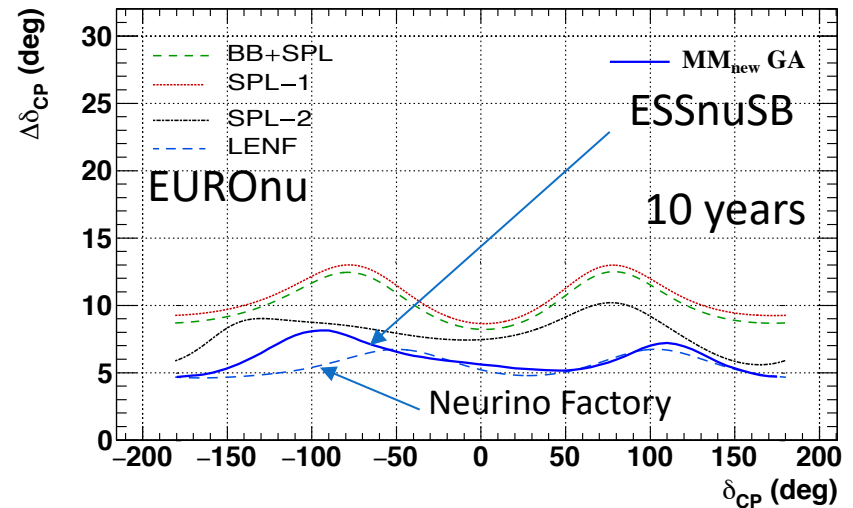
360 km



Precision measurements

more in <https://arxiv.org/abs/2107.07585>

+many technical achievements but no time to show and can answer questions afterwards...



How to progress further?

- The natural path after a CDR is to focus the work on **prototyping** and detailed **engineering** towards full demonstration of the concepts and the production of a **TDR**. Unfortunately this is difficult to obtain at this stage and the EU INFRADEV/DESTINATION calls are not adapted to these requirements.
- The ESSnuSB project is too extensive and complex for it to be possible to prepare in only 4 years a sufficient basis for an application to be included in the ESFRI list as required for an INFRADEV-02 application (R&D).
- Remaining coming possibilities:
 - INFRADEV-01 (taking example of FCC)
 - ERC-Synergy grant

ERC Calls

2021-2022 Calls Calendar

WP	Starting Grant		Consolidator Grant		Advanced Grant		Synergy Grant
	2021	2022	2021	2022	2021	2022	2022
Open	25/02/2021	23/09/2021	11/03/2021	19/10/2021	20/05/2021	20/01/2022	15/07/2021
Closure	08/04/2021	13/01/2022	20/04/2021	17/03/2022	31/08/2021	28/04/2022	10/11/2021
Budget	619 M	757 M	633 M	784 M	626 M	561 M	300 M

up to 10+4 M€

WP	Proof of Concept	
	2022	2022
Open	15/07/2021	16/11/2021
Cut-off dates or closure		15/02/2022
	14/10/2021	19/05/2022
Budget		29/09/2022
	EUR 25 M	EUR 25 M

- quite complex application
- full HIFI would be the best for this

Due to the start of a new Framework Programme, the calendar for ERC calls for upcoming and future calls differ from previous years.

We are aware that it is important for applicants to have an idea of the 2022 call dates. The Work Programme 2022 is not yet approved, thus **the dates indicated for the 2022 calls are tentative and subject to change.**

<https://erc.europa.eu/news/calls-2022-tentative-dates>

INFRADEV Call

HORIZON-INFRA-2022-DEV01

Developing European Research Infrastructures to maintain global leadership

Deadline: **24 March 2022**

Topics	Type of Action	Budgets (EUR million)	Expected EU contribution per project (EUR million)	Number of projects expected to be funded
		2022		
Opening: 10 Nov 2021 Deadline(s): 24 Mar 2022				
HORIZON-INFRA-2022-DEV-01-01	RIA	24.00	1.00 to 3.00	10
Overall indicative budget		24.00		

For the moment, we only discuss this possibility, which for us is the most likely to happen

What to do under these conditions?

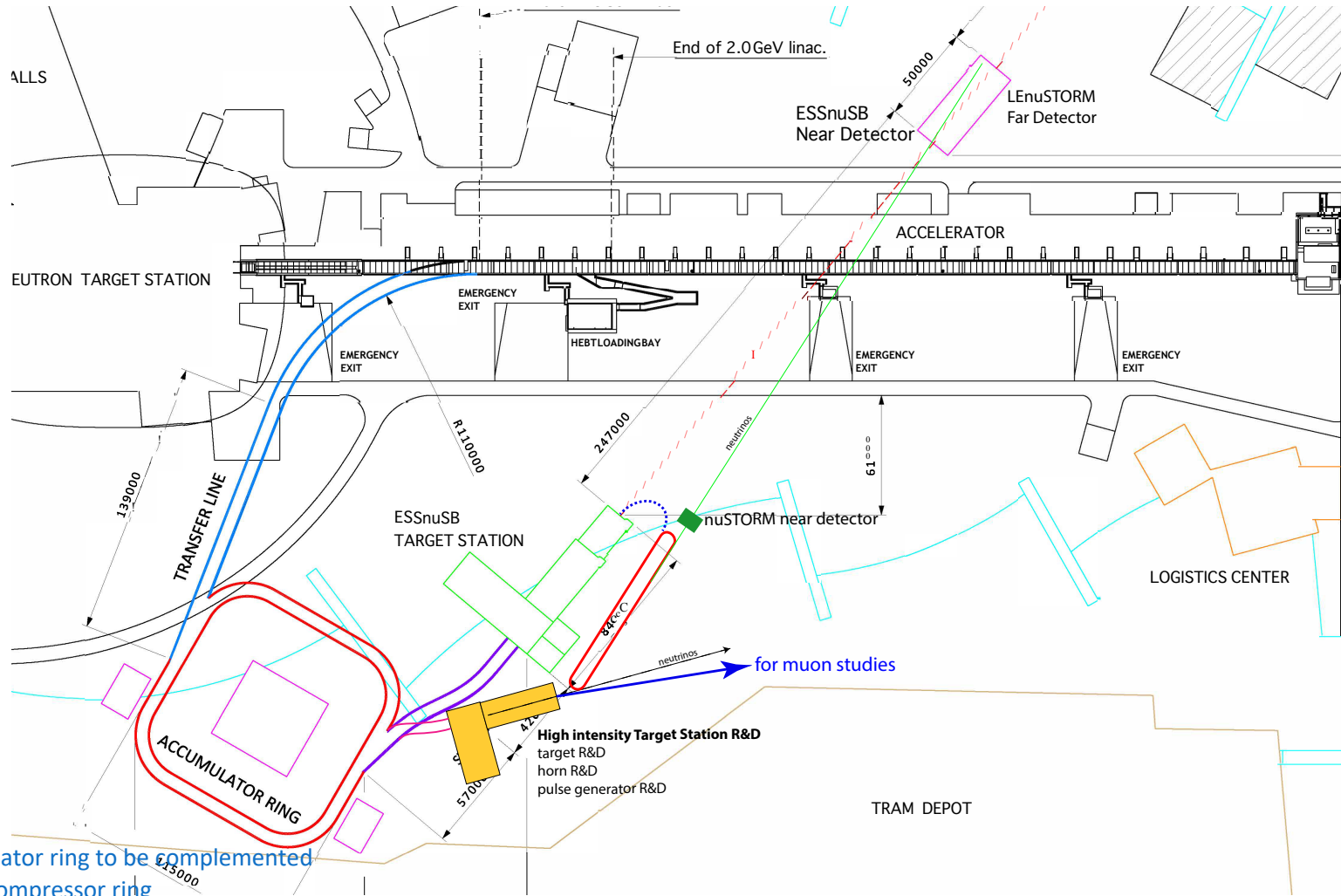
- **Further important studies needed before start ESSnuSB construction.**
 - supplementary studies required for the present proposal (according to present WP conclusions),
 - site specific civil underground engineering: at ESS-site and far detector site,
 - preparation of the R&D phase,
 - detailed studies 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.
- **Additional pillars for ESSnuSB extension proposals (HIFI synergies):**
 - Extend the present design to include the possibilities offered by the ESS H⁻ beam for a competitive high intensity frontier research program to be planned in two phases:
 - **Phase 1:** before the approval of the construction of the ESSnuSB.
 - **Phase 2:** after the approval, preparation in parallel to the neutrino beam construction/operation of ESSnuSB.

Advantages of completion of the project in phases

- Parts of the project can start earlier and can also serve as prototyping phase for the final project.
- Take profit of synergies with other projects (muons).
- Financing becomes more feasible.
- Increase attractivity (to young people).



Proposed scenario for the period 2022-25



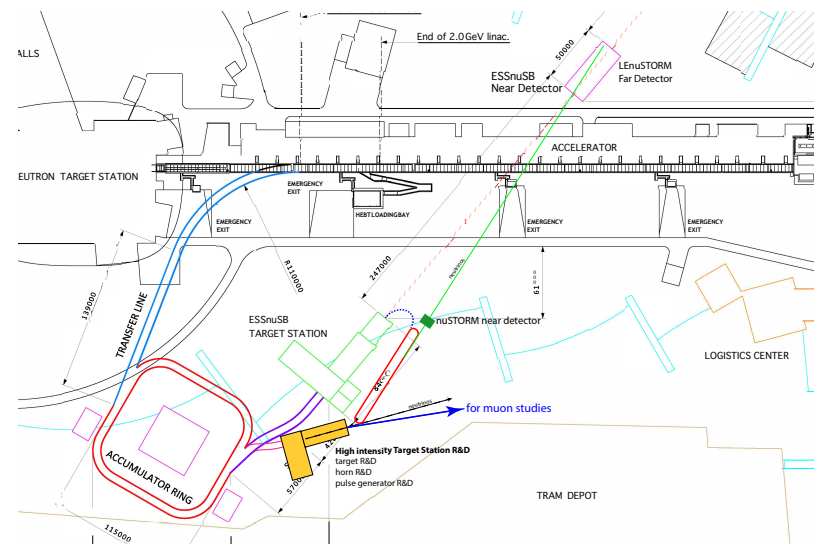
Accumulator ring to be complemented with a Compressor ring

Proposed scenario for the period 2022-25

Possible WPs:

1. Civil engineering (ESS and mine site), safety and environment preservation.
2. Linac, accumulator/compressor and LEnuSTORM race-track.
3. ¼ Target Station, hadron/muon production and muon extraction for Low Energy nuSTORM.
4. Detectors and physics performance (synergy between ESSnuSB and LEnuSTORM).
5. Partial design studies of initial steps towards a Muon Collider, of the compression of $1.3 \mu\text{s}$ bunches of 10^{14} protons to order 1 ns and a target that can withstand such short bunches.

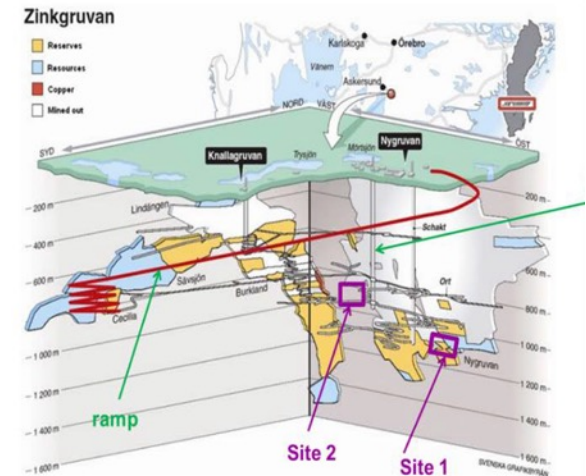
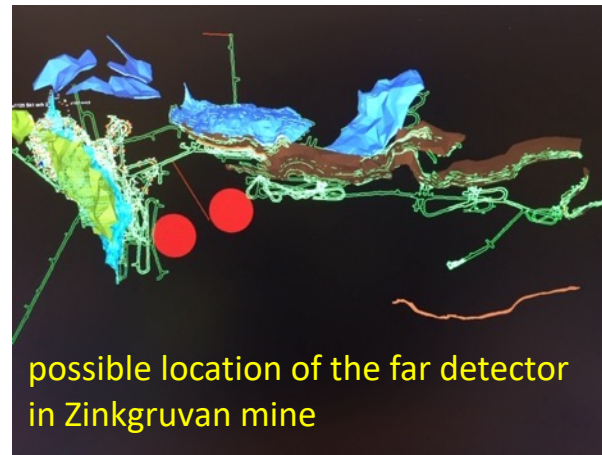
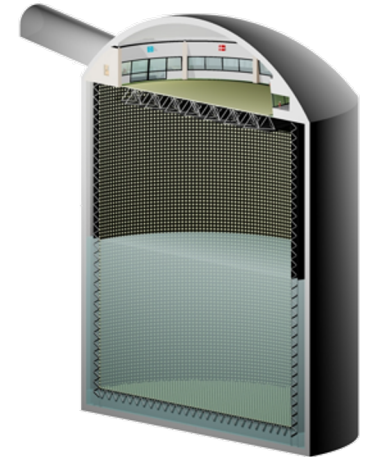
preparation of the R&D phase



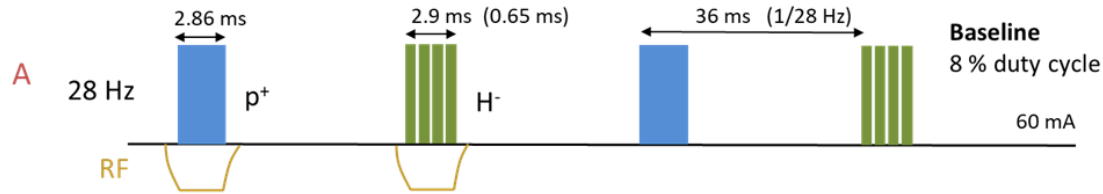
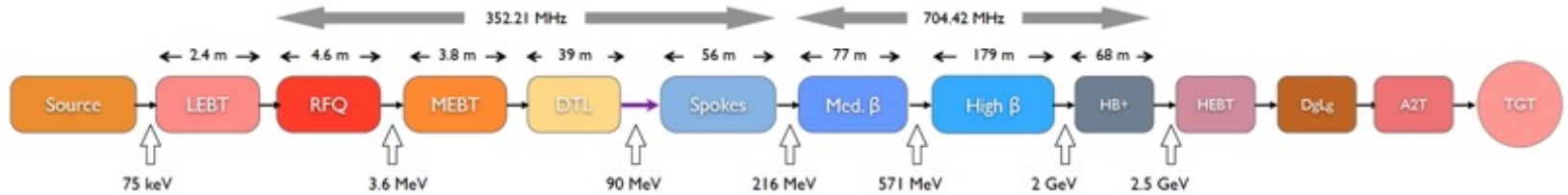
The asset: in ~2025 (or so...) ESS will have the LINAC in operation with a MMW proton beams the high scientific potential of which **cannot be ignored or disregarded.**

ESS site and mine site civil engineering

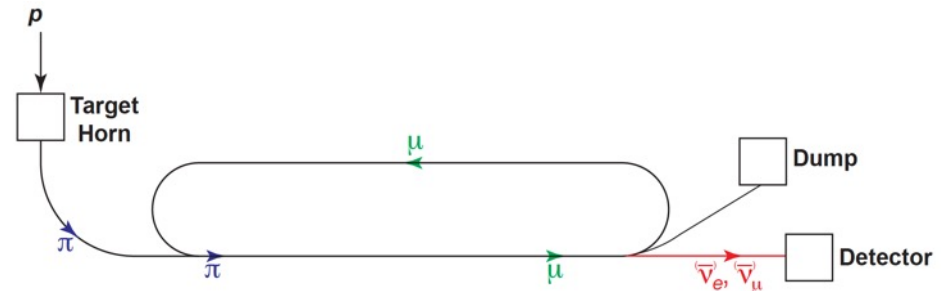
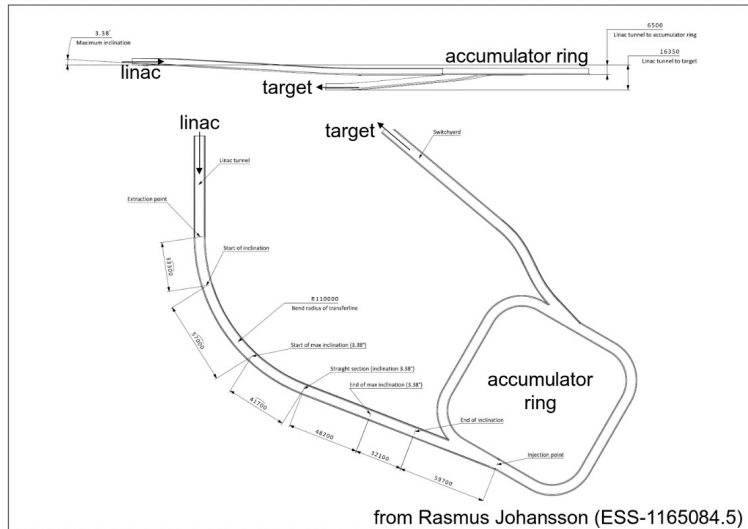
- Design Study of civil engineering
 - ESS site
 - cavern constructions at Garpenberg and/or Zinkgruvan
- Licencing
- Safety
- Environment protection



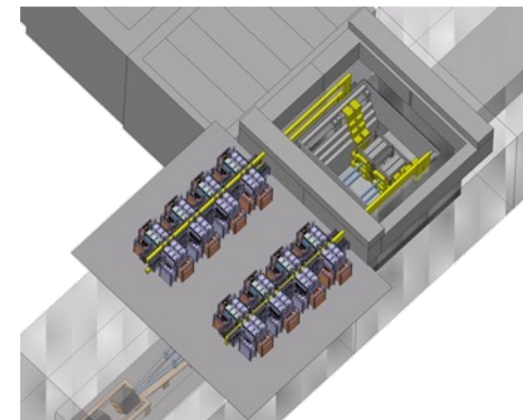
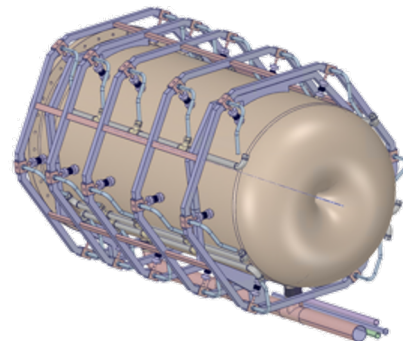
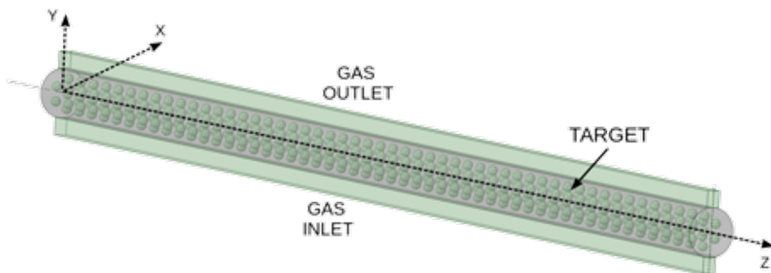
Linac, accumulator and race-track



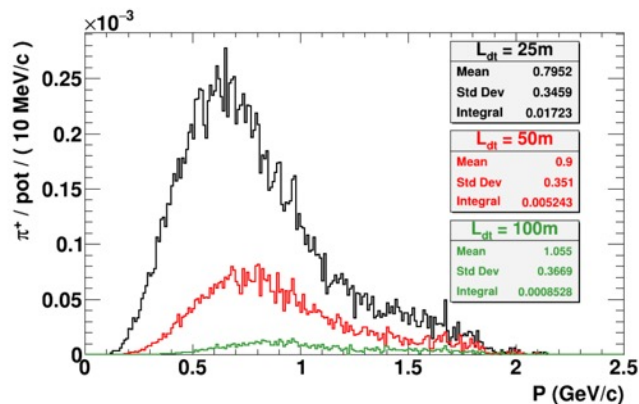
Linac operation mode



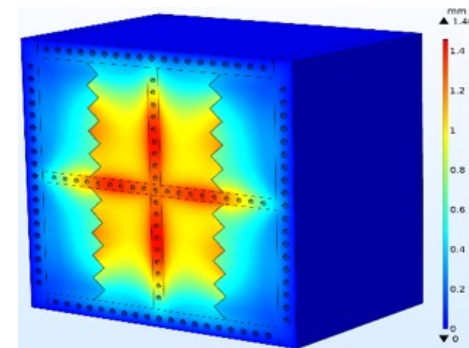
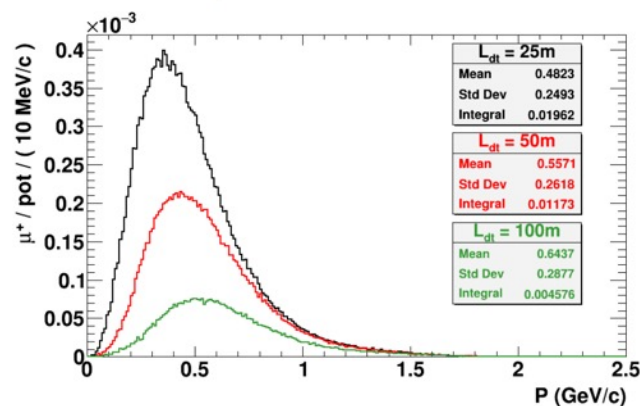
Targetry, hadron production, muon extraction



Pion momentum distribution in a 4m x 4m aperture



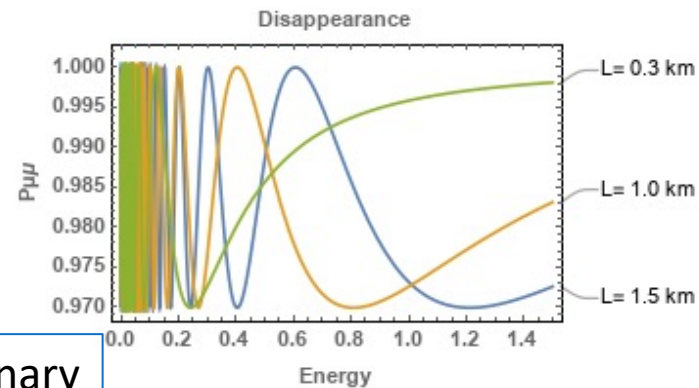
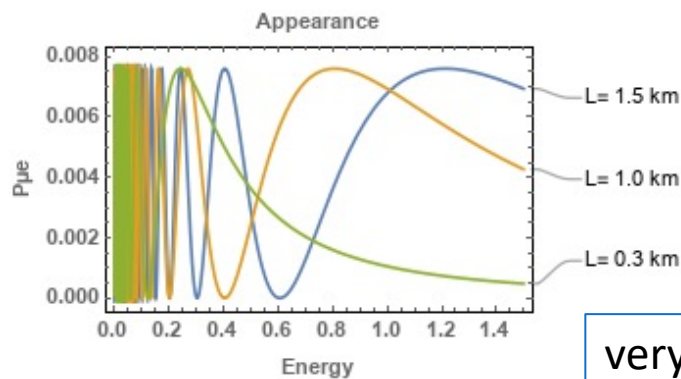
Muon momentum distribution in a 4m x 4m aperture



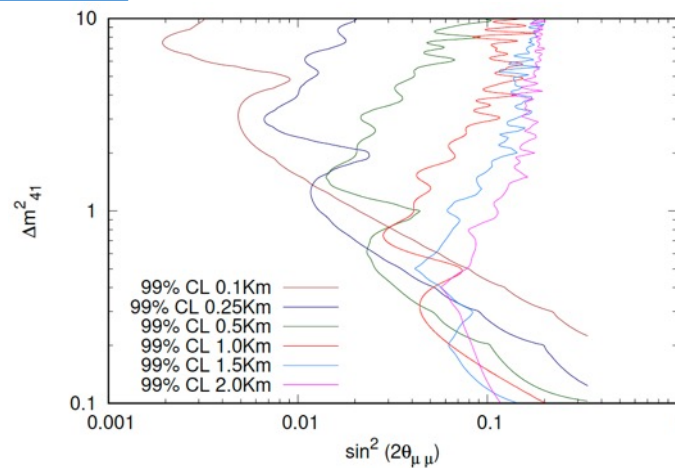
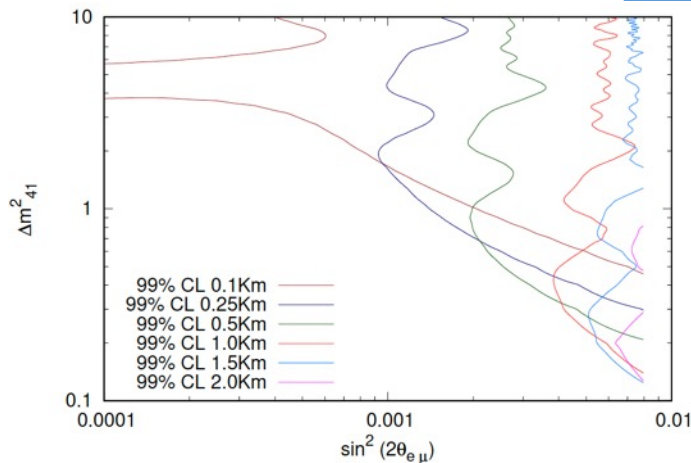
Low Energy nuSTORM

~0.5 GeV muons

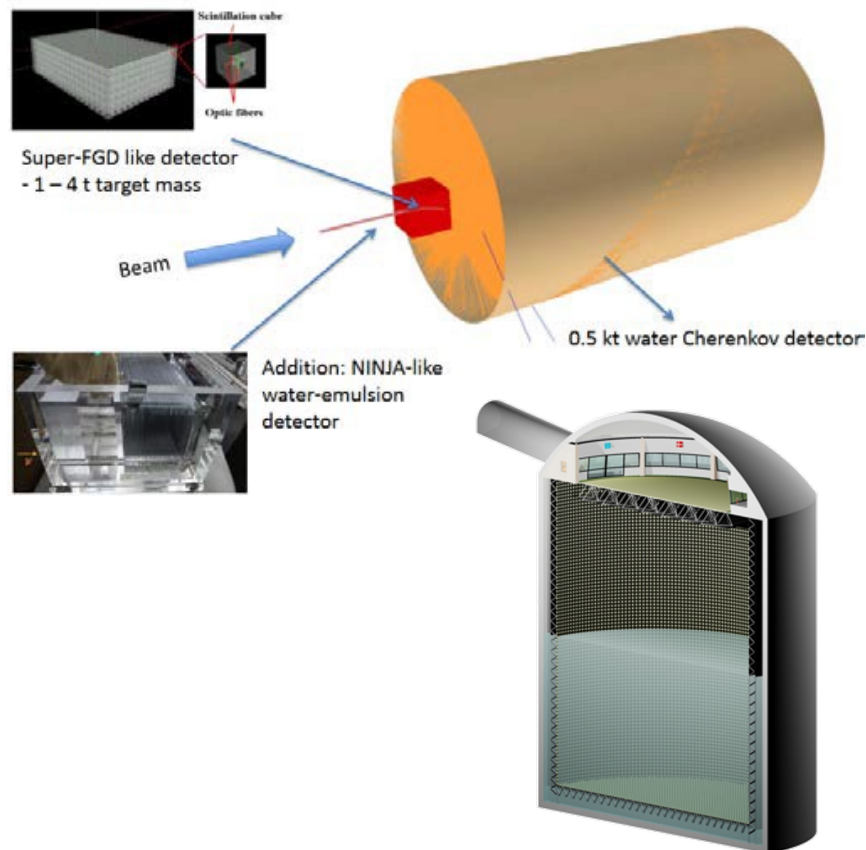
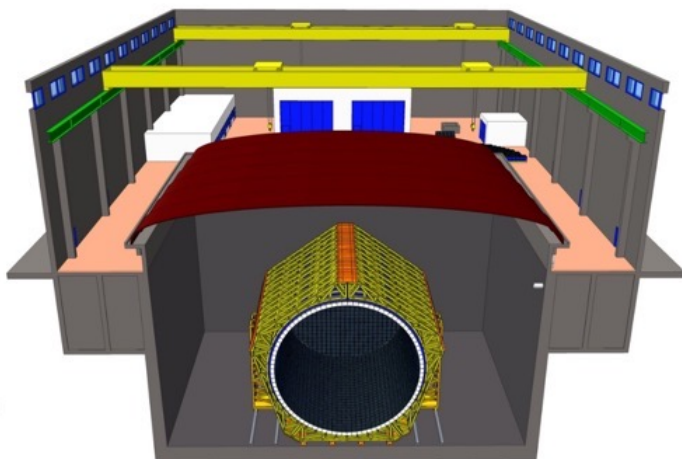
- sterile neutrinos
- cross-section measurements



very preliminary



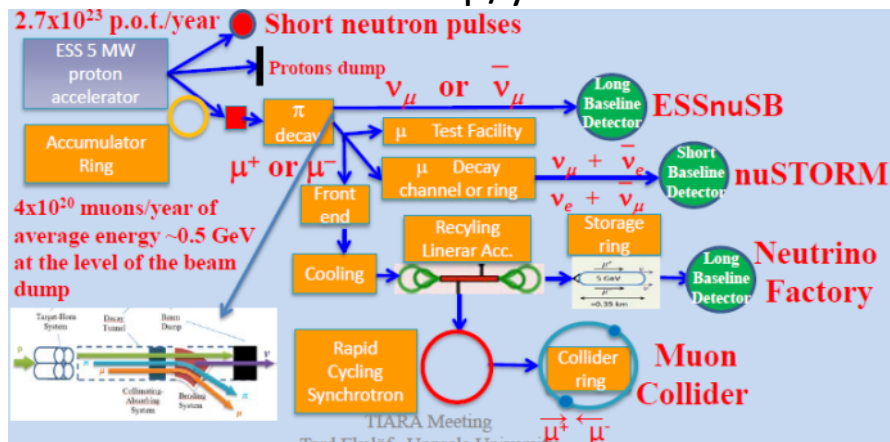
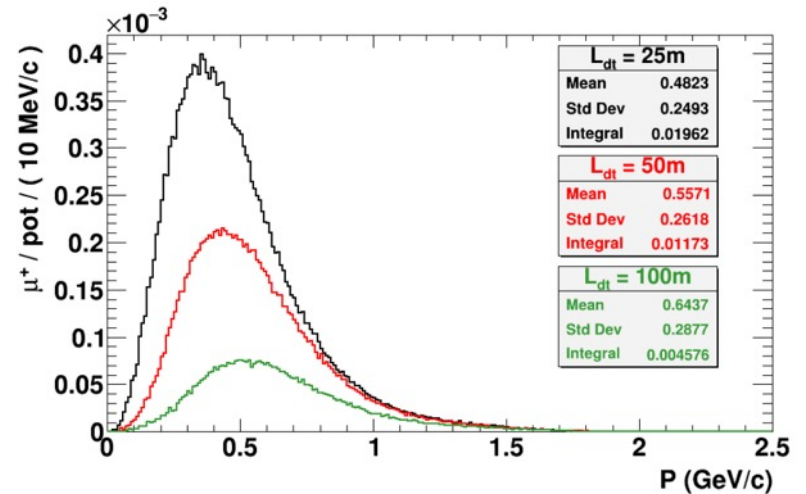
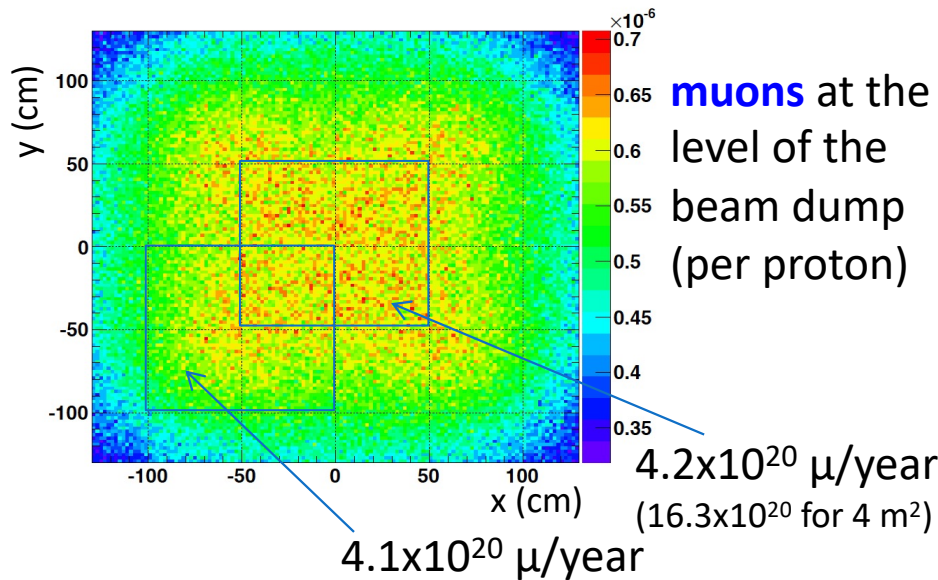
Detectors and physics performance



- Near and Far detectors
 - cross-section measurements
- Physics performance
 - LEnuSTORM (sterile neutrinos)

astroparticle physics program with the far detector

Muons for future applications



- muon cooling
- Neutrino Factory
- Muon Collider
- muon polarisation?

Towards ESSnuSB construction

- The ESSnuSB extensions and intermediate phases would further justify the investment on ESS and place it as world leading lab.
- Could also be part and receive funds from other HEP programs if could provide timely answers to key questions (as muon cooling).
 - timing is critical, decisions to be taken around 2027 (fourth Strategy Update) !
- Such an extension could be an important initial step,
 - if realized, would be an important achievement towards the full ESSnuSB realization



Conclusion

- ESS will have the LINAC in operation with a MMW proton beams, the high scientific potential which **cannot be ignored or disregarded** when planning the future of particle physics.
- ESSnuSB Design Study made a huge progress mainly concerning the physics performance.
- Towards R&D, further studies are necessary.
- Preparing the project in phases increases its feasibility.
- Synergies help to increase the number of financial contributors but also to attract more people.
- At this moment, the only way we have to go forward is an INFRADEV-01 application!



Backup

ESSnuSB STRUCTURE: PARTICIPATING INSTITUTIONS/ ORGANISATIONS

List of ESSnuSB Participating Institutions / Organisations

#	Institutions / organisations name	Acronym	Country
1	Centre National de la Recherche Scientifique	CNRS	France
2	University of Uppsala	UU	Sweden
3	Kungliga Tekniska Hoegskolan	KTH	Sweden
4	European Spallation Source Eric	ESS	Sweden
5	University of Cukurova	CU	Turkey
6	Universidad Autonoma de Madrid	UAD	Spain
7	National Center for Scientific Research "Demokritos"	DEMOKRITOS	Greece
8	Instituto Nazionale di Fisica Nucleare	INFN	Italy
9	Ruder Boskovi Instgitute	RBI	Croatia
10	Sofiiski Universitet Sveti Kliment Ohridski	UniSofia	Bulgaria
11	Lunds Universitet	ULUND	Sweden
12	Akademia Gorniczo-Hutnicza Im. Stanislaw Staszica w Krakowie	AGH / AGH-UST	Poland
13	European Organization for Nuclear Resarch	CERN	Switzerland
14	University of Geneva	UNIGE	Switzerland
15	University of Durham	UDUR	United Kingdom

11 countries

- Starting date: 01/01/2018
- Ending date: 31/12/2021 → 31/03/2022,
- Duration: 48+3 Months,
- 3 months extension due to COVID19
- Kick-off meeting: 15 January 2018, Lund (ESS),
- 90% of the budget already received,
- All deliverables and milestones ready on time (some rescheduling due to COVID19 has been arranged with the EU Project Officer)