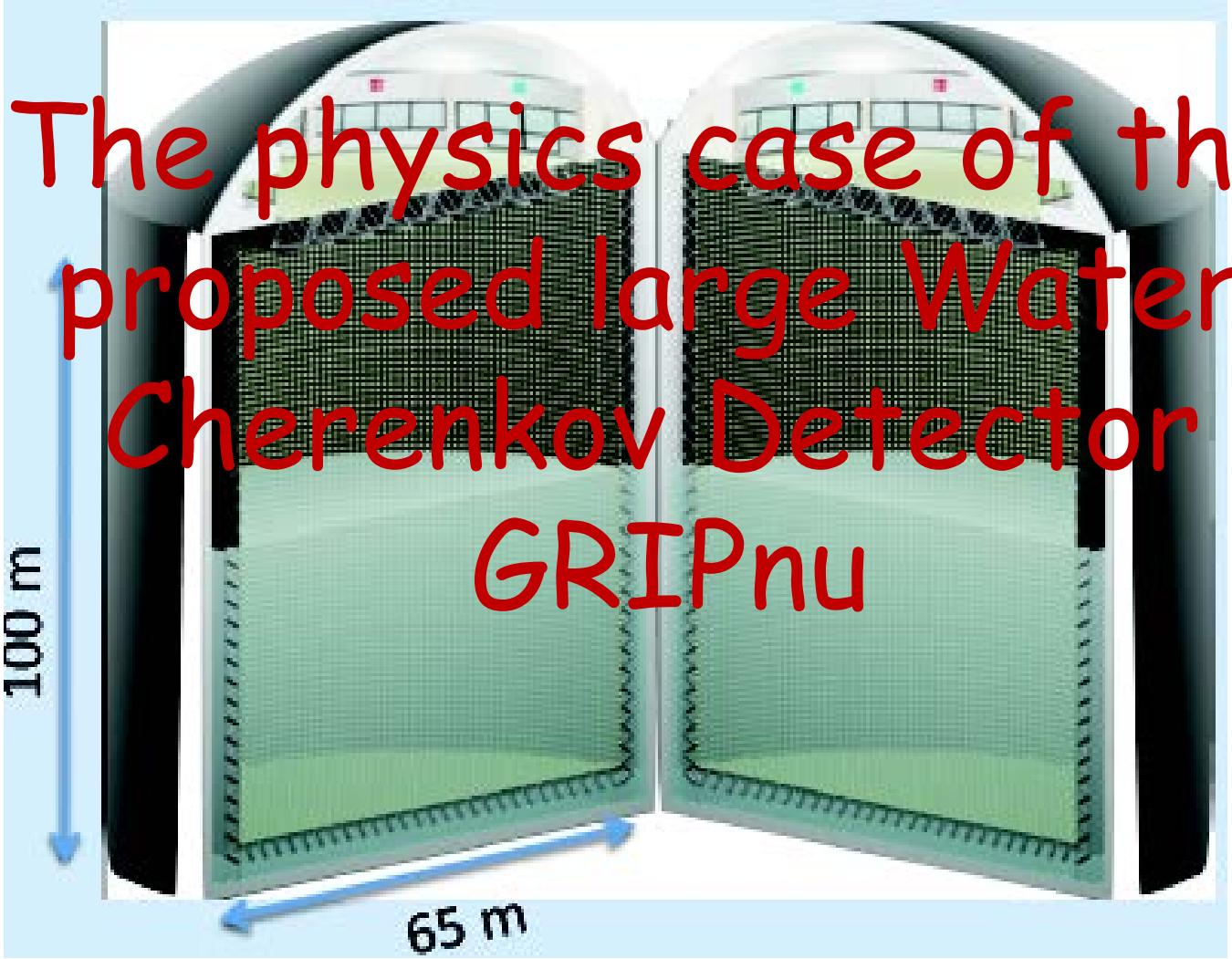
The physics case of the proposed large Water Cherenkov Detector GRIPnu

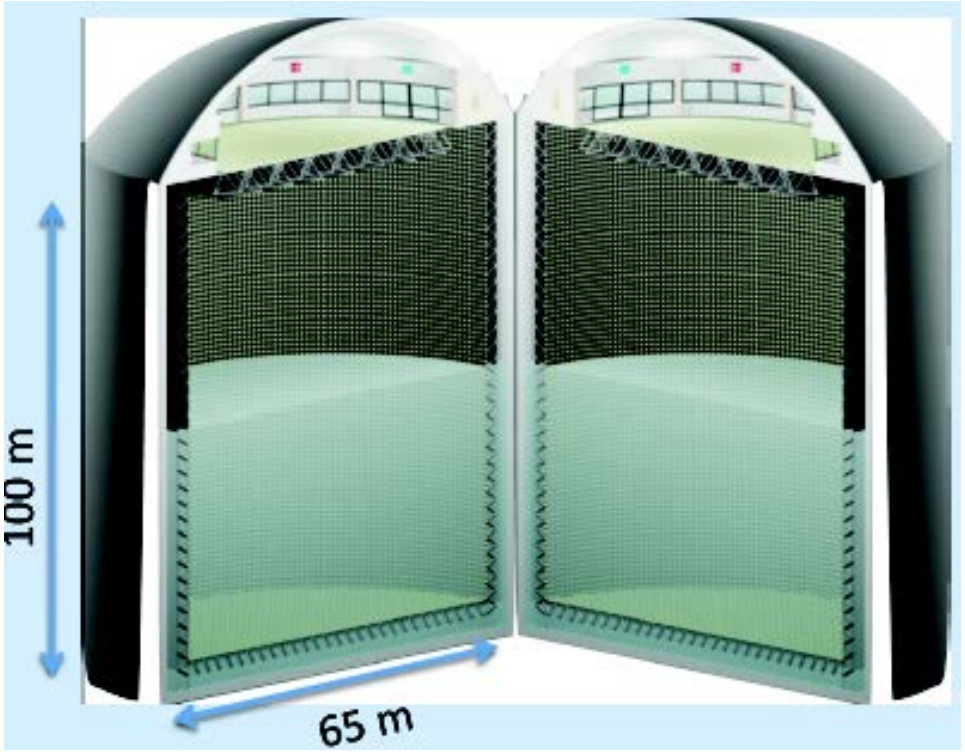


SFS Particle Days Stockholm 6 November 2017
Tord Ekelöf
Uppsala University

The MEMPHYS WC Detector

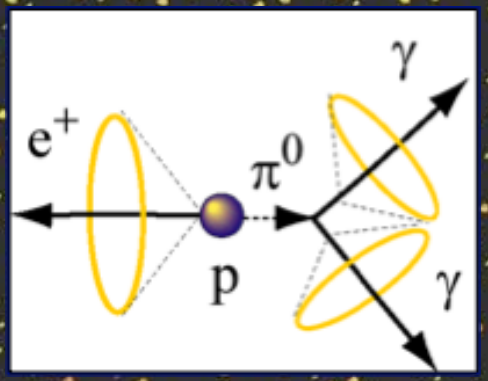
(MEgaton Mass PHYSics)

- Proton decay
- SuperNova neutrinos
- Supernovae "relics"
- Solar Neutrinos
- Atmospheric Neutrinos
- Neutrino Oscillations



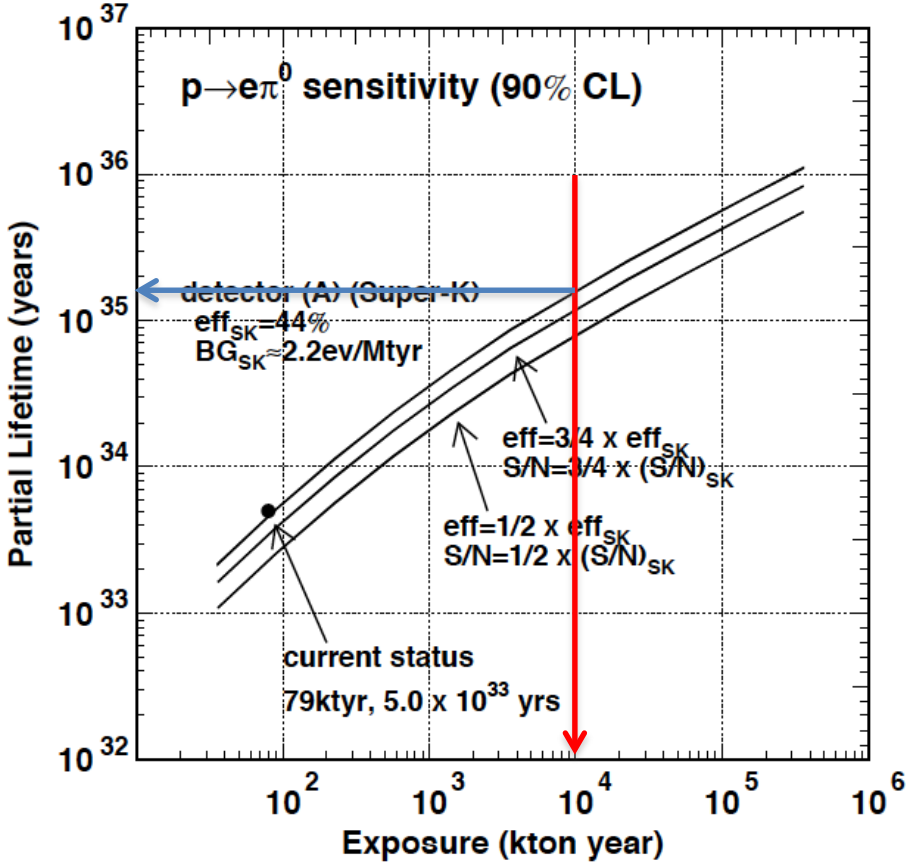
- 500 kt fiducial volume (~20xSuperK)
- Readout: ~240k 8” PMTs
- 30% optical coverage **(arXiv: hep-ex/0607026)**

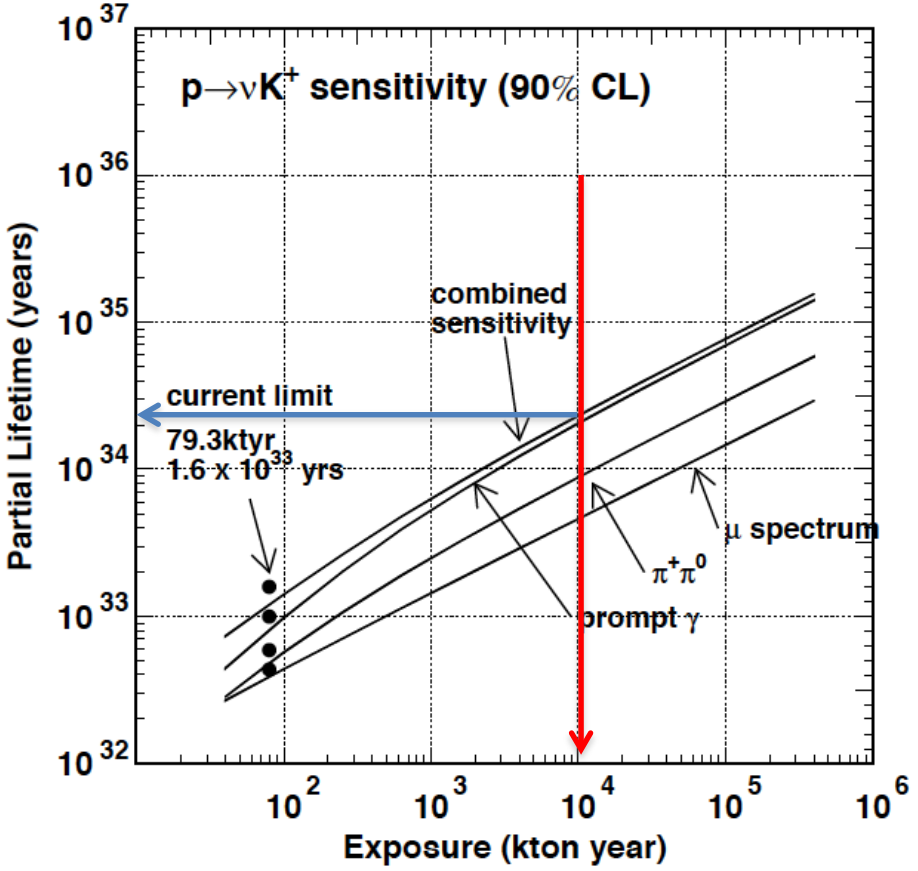
Proton Decay



ESSnuSB-MEMPHYS sensitivities

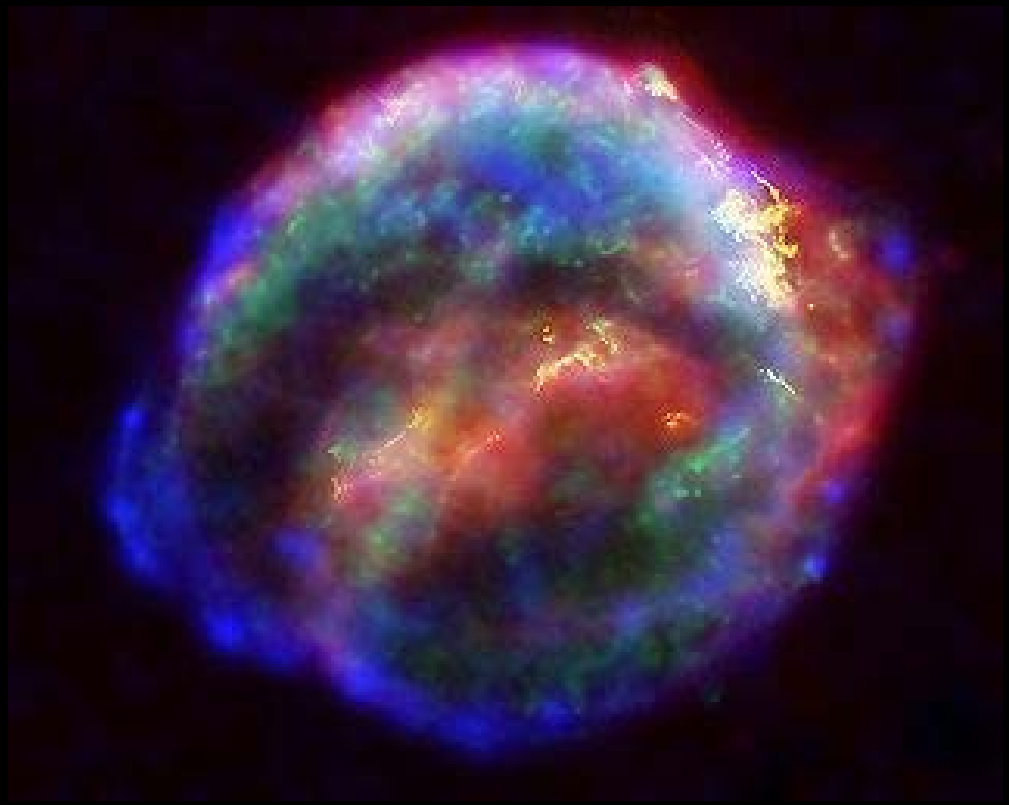
proton decay





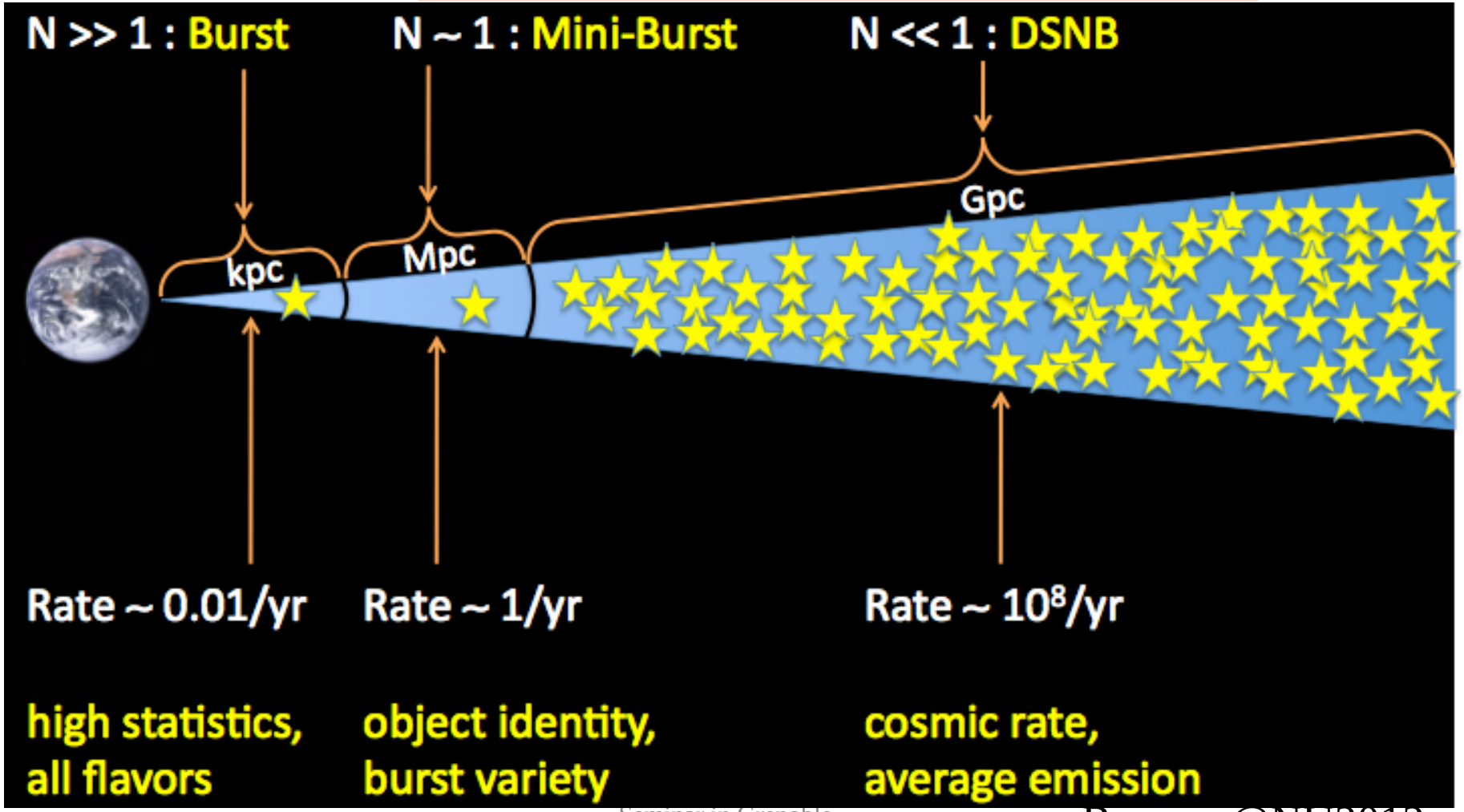
(arXiv: hep-ex/0607026)

Supernova



Distance scale and exp'd rate

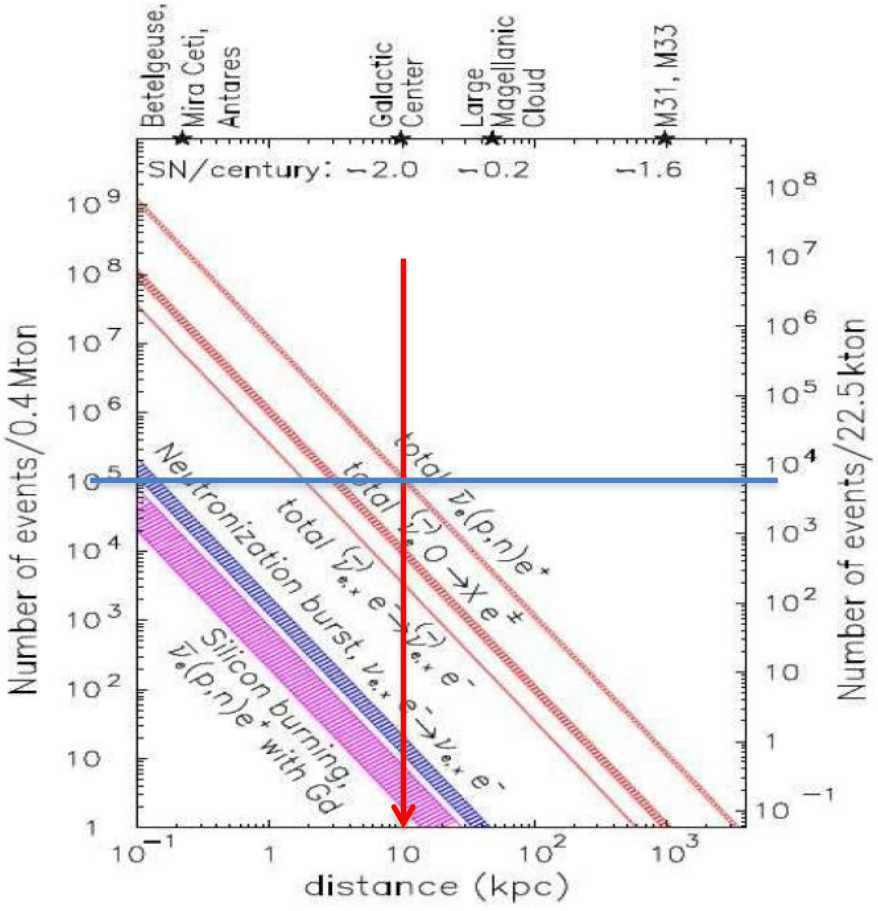
Milky way	Nearby galaxies	Distant galaxies



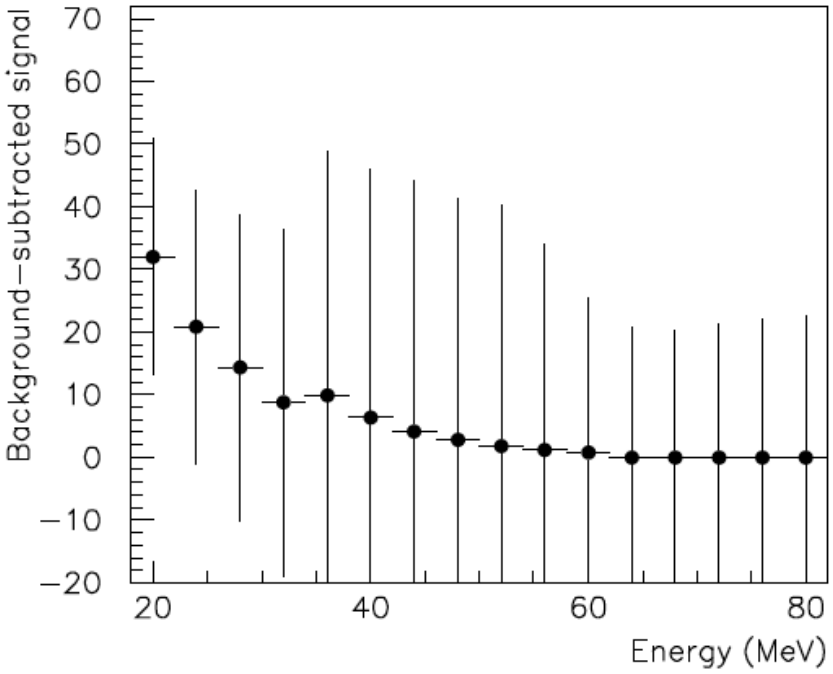
ESSnuSB-MEMPHYS sensitivities

Supernova explosion and relics

MEMPHYS



SUPERK



Diffuse Supernova Neutrinos
(10 years, 440 kt)

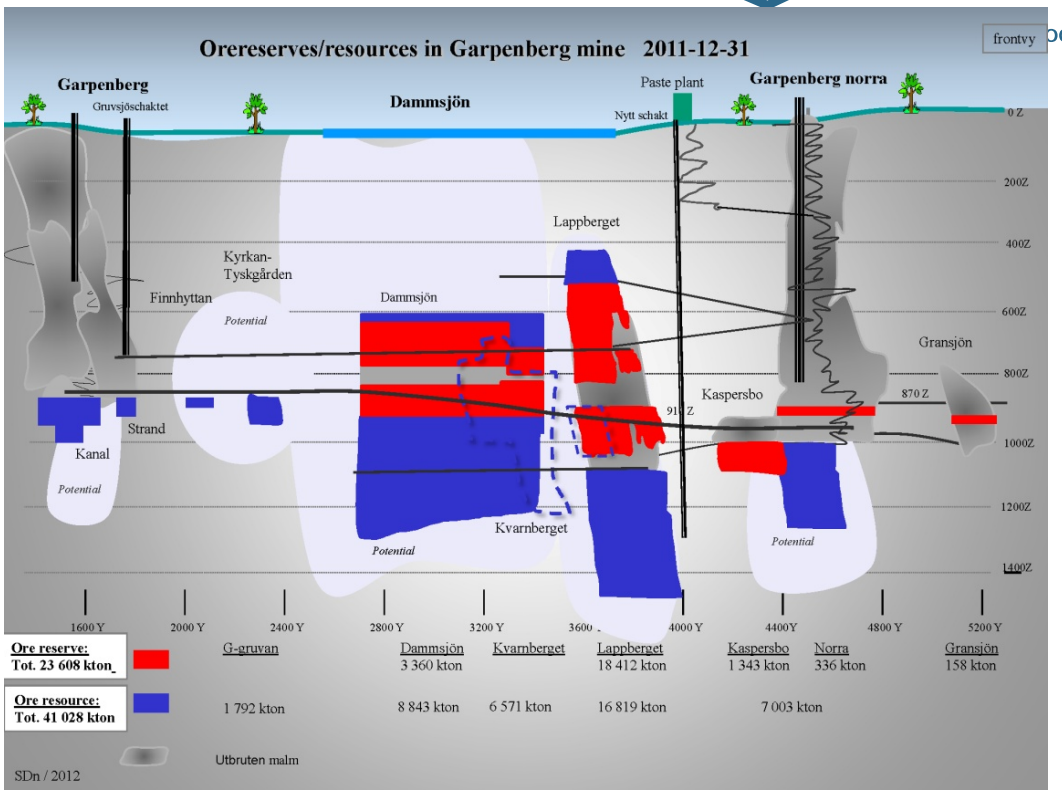
For 10 kpc: ~10^5 events

Garpenberg Mine

Distance from ESS Lund **540 km**

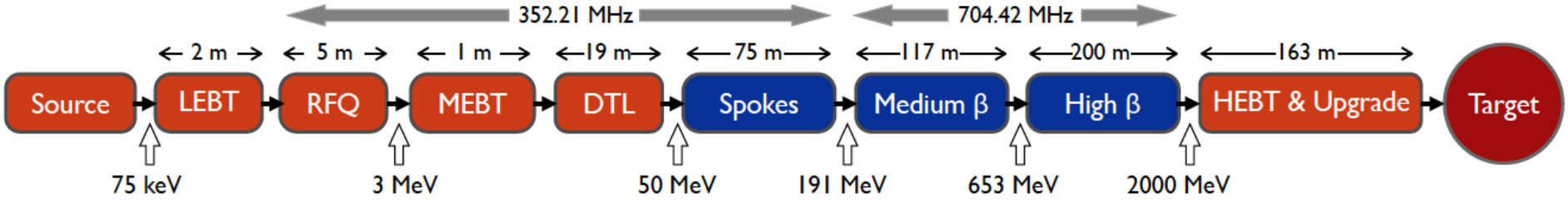
Depth 1232 m
Truck access tunnels
Previously two ore-hoist shafts

Recently a new ore-hoist shaft was taken into operation, **leaving the Garpenberg Norra shaft free for other uses**

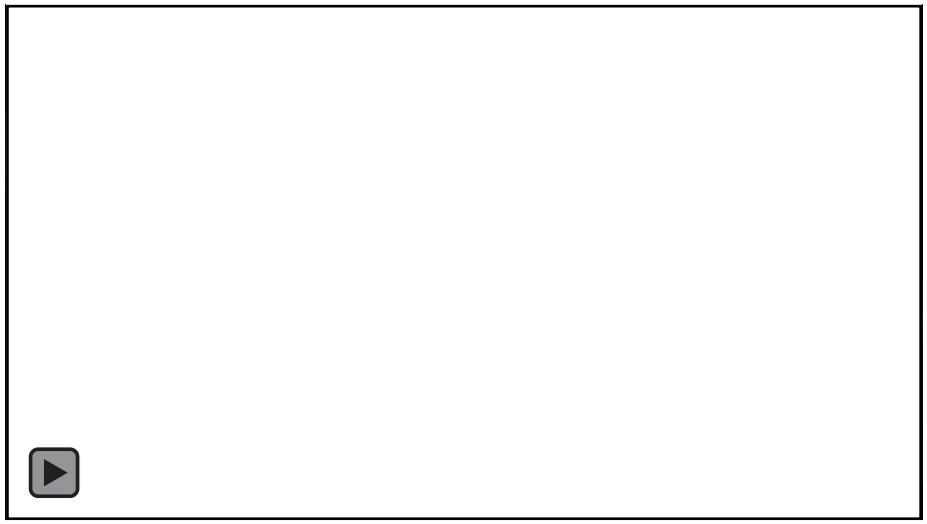


Granite drill cores

ESS proton linac is located 540 km from Garpenberg

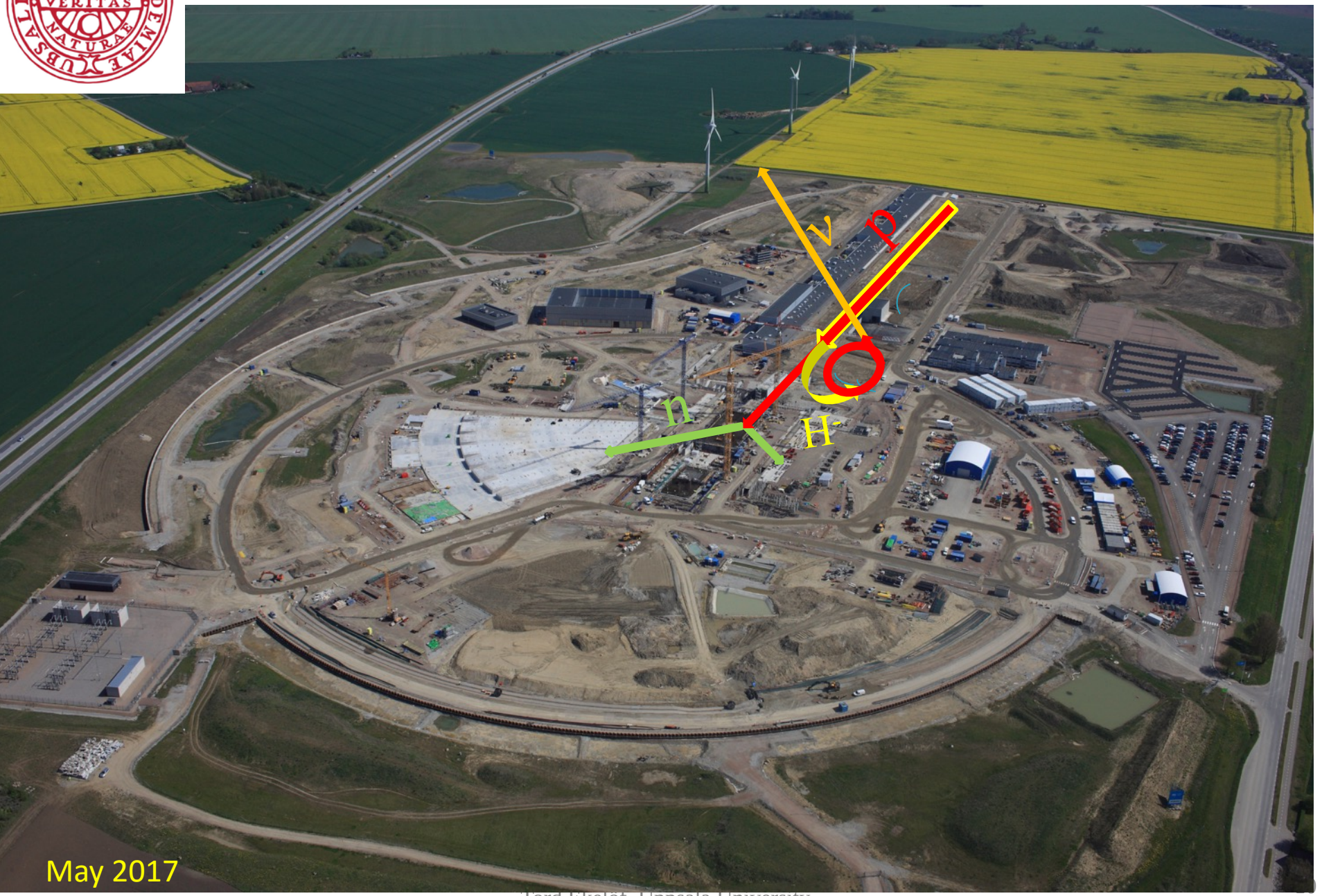


- With 5 MW average beam power and **2.7×10^{23} protons on target per year** the ESS linac will be the most powerful and intense proton accelerator in the world, ca 10 times more powerful than the current J-Park and FNAL proton accelerators
- 125 MW peak power.
- 14 pulses of 2.86 ms duration per second, each containig10^{15} protons.
- Duty cycle 4%.
- 2.0 GeV protons, up to 3.5 GeV with linac upgrades



Linac ready by 2023 (full power)

The neutron and neutrino beams



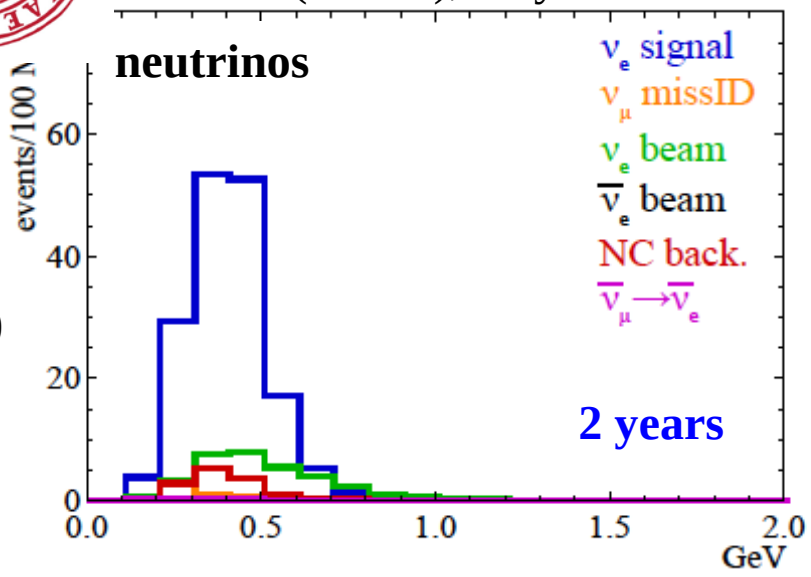
May 2017

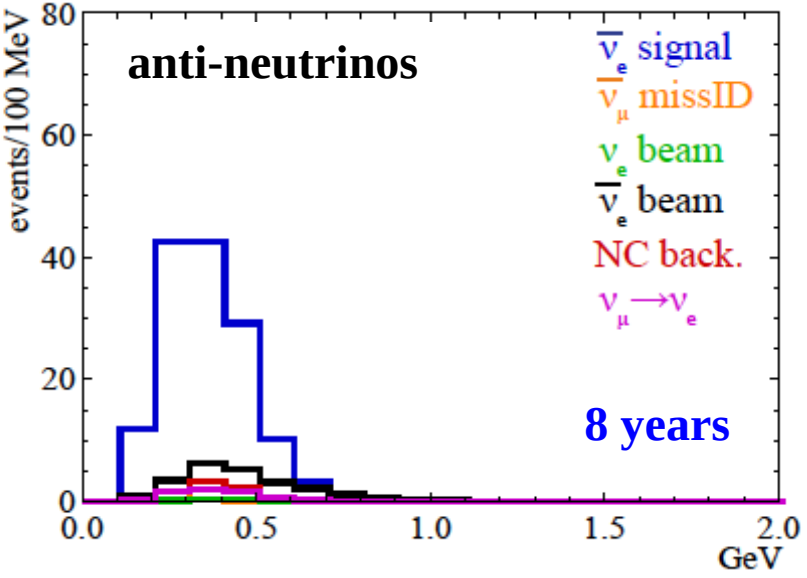
Neutrino spectra

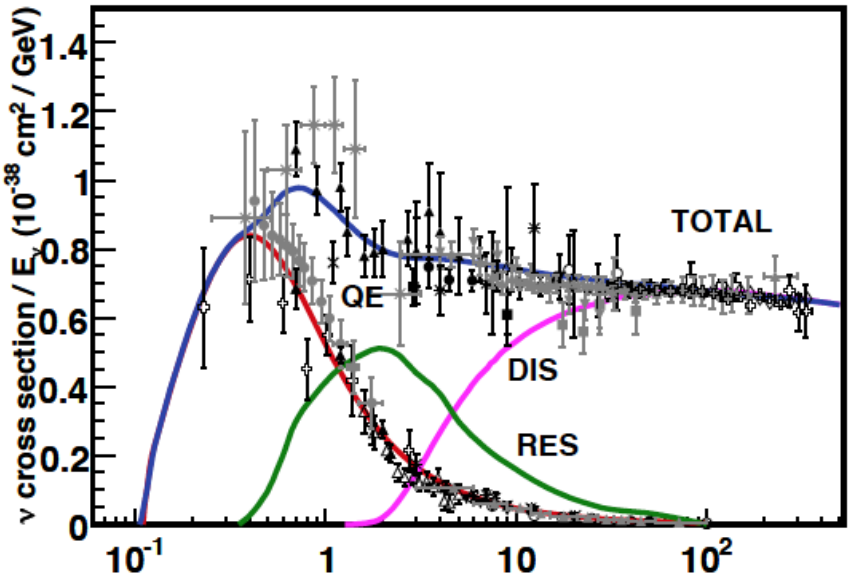
540 km (2 GeV), 10 years

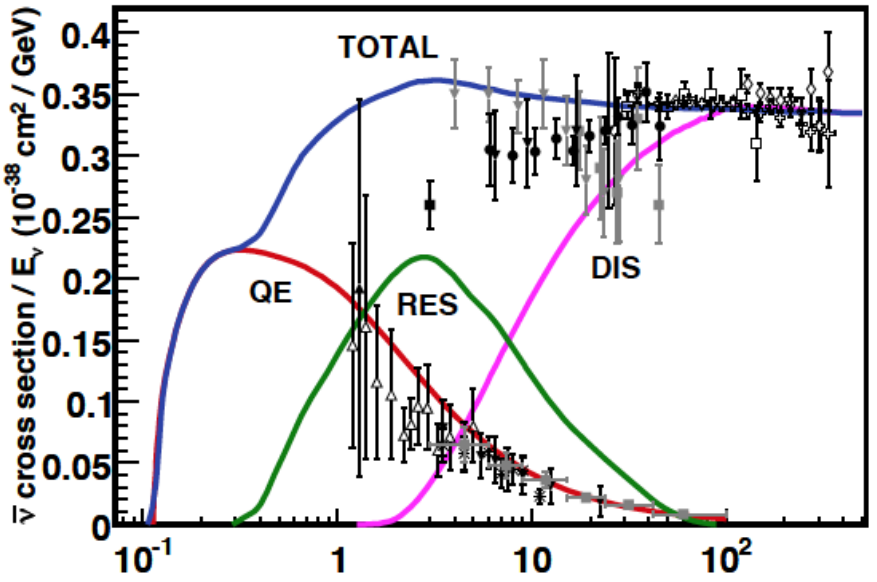
below ν_τ production, almost only QE events

$\delta_{CP}=0$

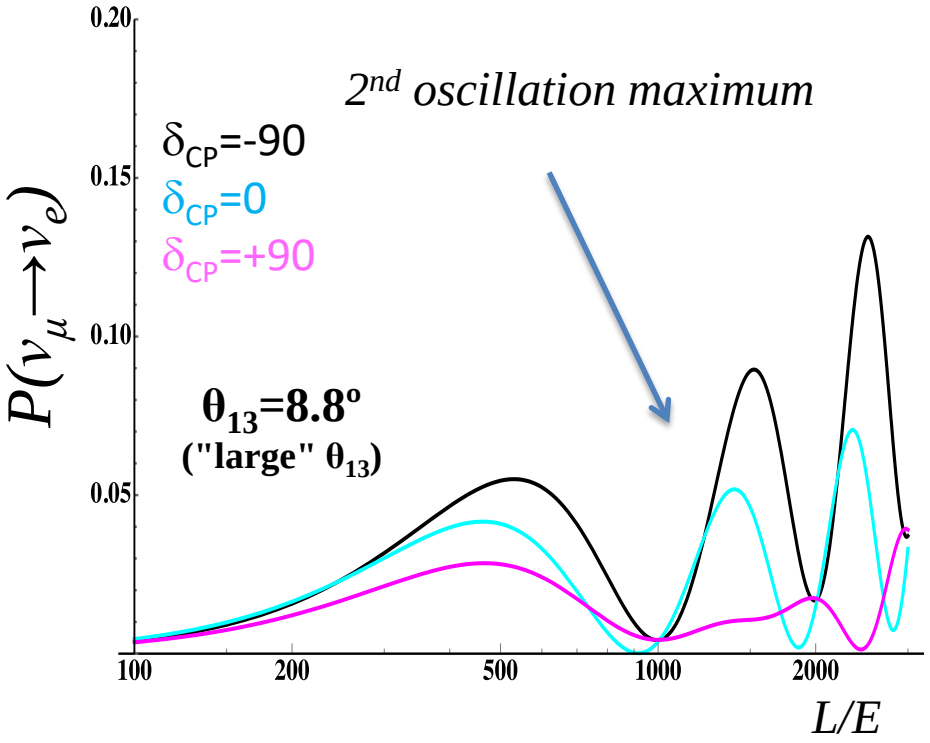




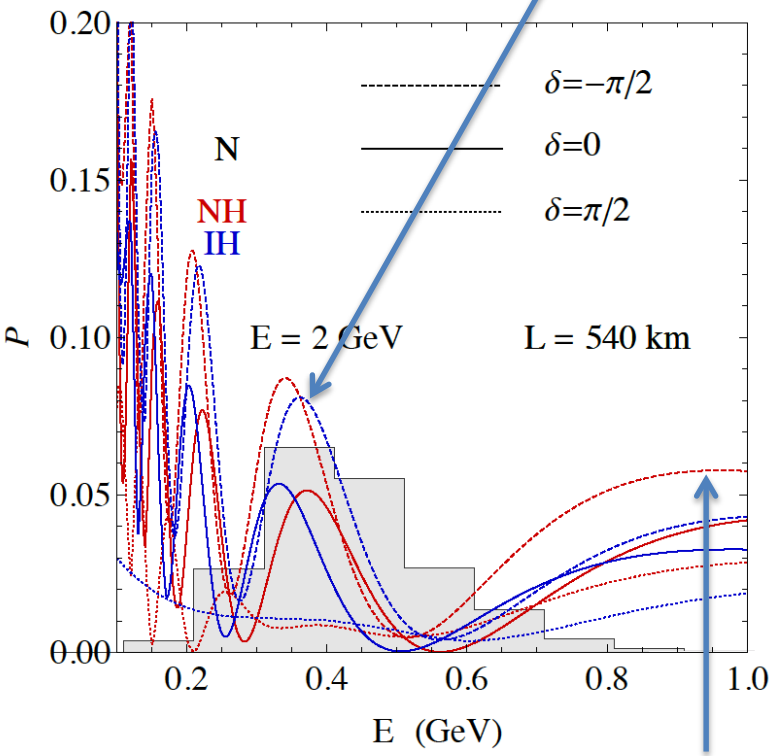




2nd Oscillation max. coverage



2nd oscillation max. well covered by the ESS neutrino spectrum

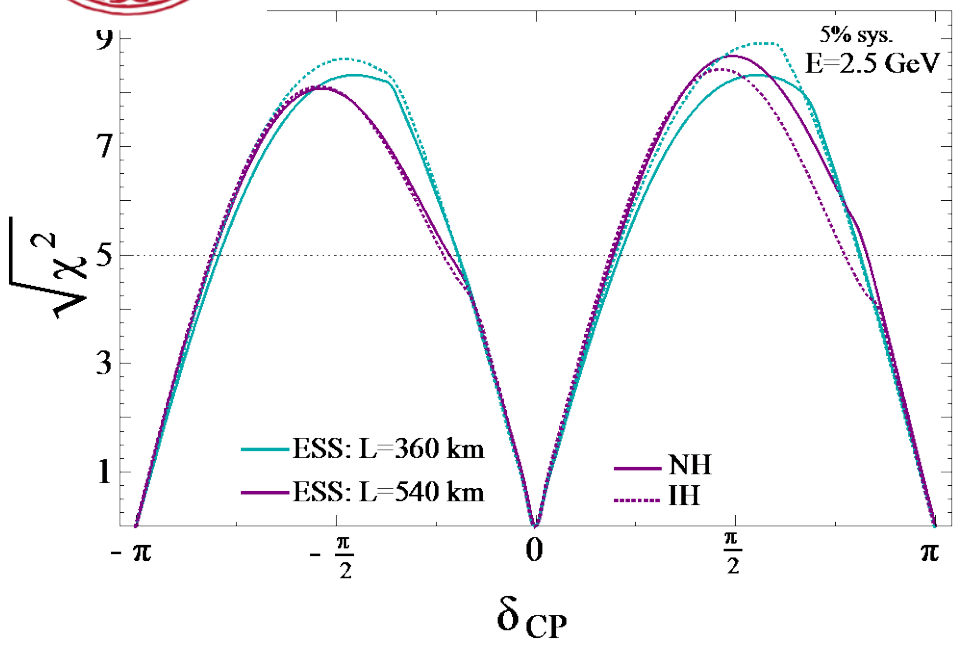


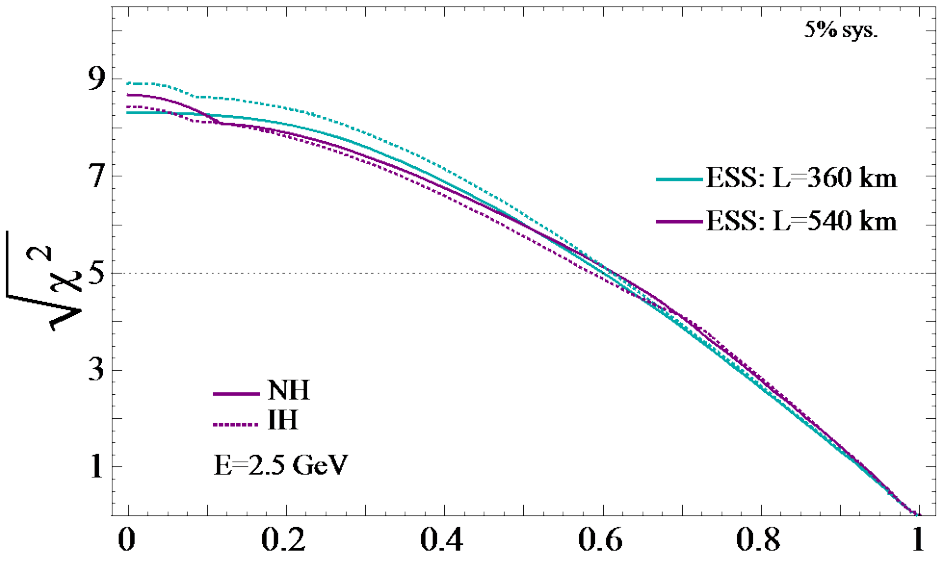
1st oscillation max.

L(2nd max) =1500 (km) x E (GeV) =1500x0.35 = 525 km

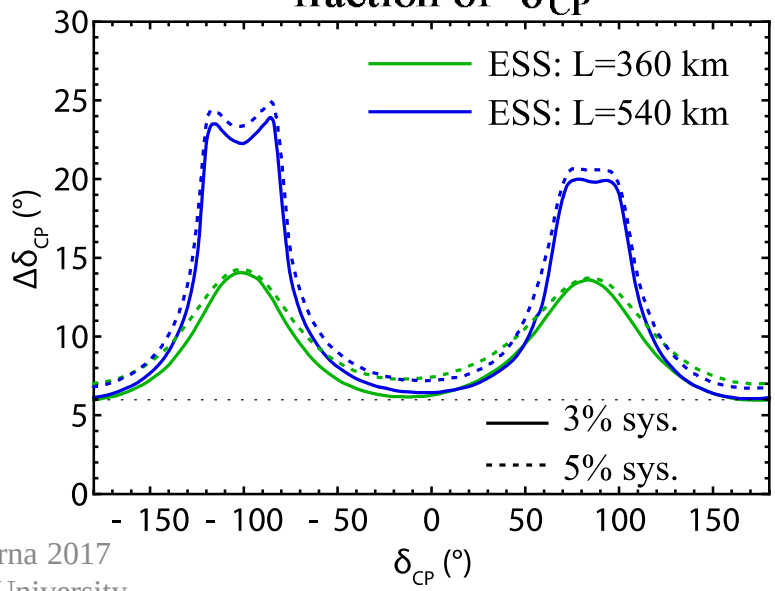
L(1st max) = 500 (km) x E(GeV) = 500x0.35 = 175 km

Physics Performance





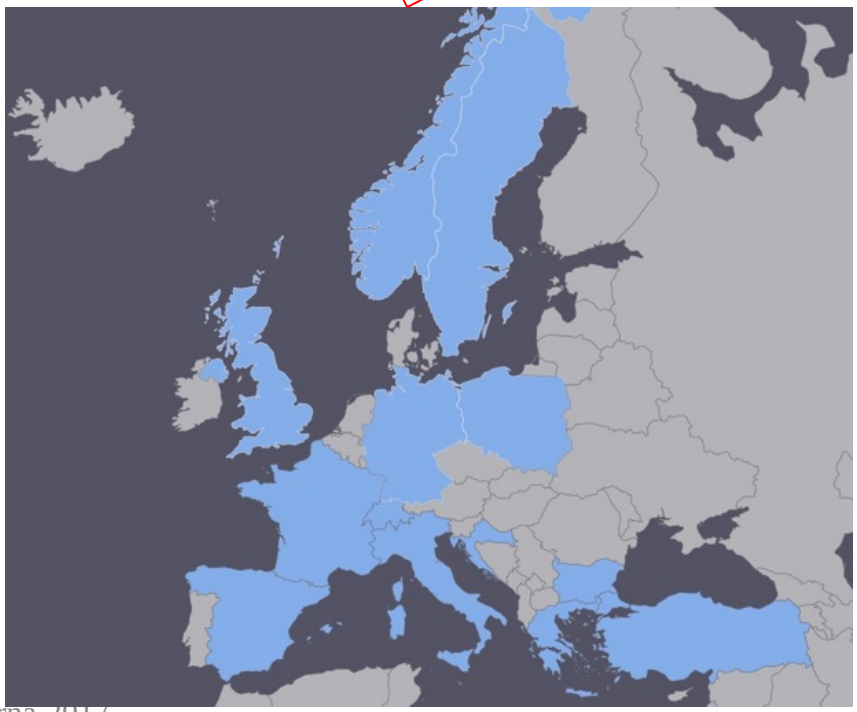
- little dependence on mass hierarchy (not so long baseline),
- δ_{CP} coverage at 5 σ C.L. up to 60%,
- δ_{CP} accuracy down to 6° at 0° and 180° (absence of CPV for these two values),
- not yet optimized facility.



EU COST project for ESSvSB networking approved in 2016

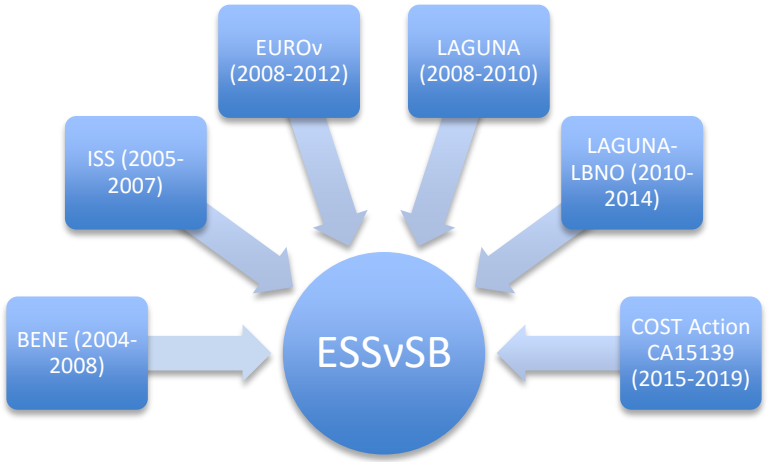
- **EuroNuNet** : *Combining forces for a novel European facility for neutrino-antineutrino symmetry violation discovery* (**http://www.cost.eu/COST_Actions/ca/CA15139**
- Granted 0.5 MEUR)
- **Major goals of EuroNuNet**:
  - to aggregate the community of neutrino physics in Europe to study the ESSνSB concept in a spirit of inclusiveness,
  - to impact the priority list of High Energy Physics policy makers and of funding agencies to this new approach to the experimental discovery of leptonic CP violation.
  - 13 participating countries (network still growing).

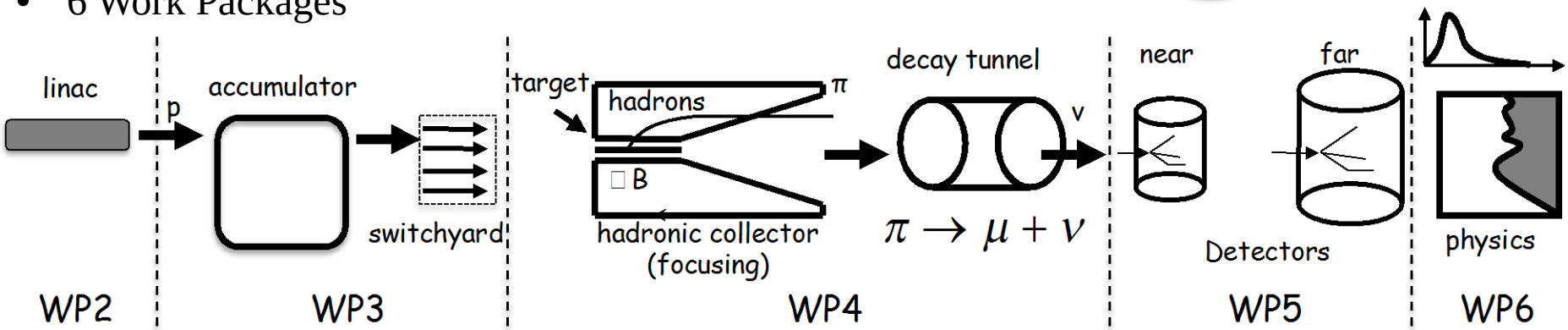
Special session at the NUFACT2017 worshop



A EU/H2020 project for a ESSvSB Design Study approved in August 2017 (Call INFRADEV-01-2017)

- **Title of Proposal**: Discovery and using an intensive neutrino Super Beam generated with the exceptionally powerful ESS linear accelerator
- **Duration: 4 years**
- **Total cost: 4.7 M€**
- **EU grant: 3 M€**
- 15 participating institutes from 11 European countries including CERN and ESS
- 6 Work Packages





EU excellence criterion
4.5 of 5 poins

The proposal is addressing the use of ESS proton linac which would be tuned to provide up to an order of magnitude higher power proton beams than the present linear accelerators. The upgrade of the linac to high intensity neutrino beam to address matter-antimatter asymmetry in the lepton sector is very ***ambitious, is clearly innovative and beyond-the-state-of-the-art.*** *It is a very well written proposal with clear objectives and* ***sound concept and scientific case****. The proposed methodology is credible. The project has good interdisciplinary approach.*

The proposal is timely and has advantages in costs and physics objectives over similar experiments.

Impact criterion
4.5 of 5 points

The project will have significant impact on enhancing attractiveness of Europe in future neutrino programs in the long baseline scheme. *The technical and scientific impacts due to the upgrade of ESS linac power, the construction of a high flux neutrino beam, implementation of the near and far detectors and also the potential discovery of CP violation in the lepton sector are high.* ***The project is strongly supported by the main players in the field****. CERN established a strong scientific case for long baseline neutrino program exploring CP violation. In addition, the proposed design is recognized to address all critical issues by the scientific community.* ***The project has a potential to increase and diversify the user community of ESS. Building an infrastructure in an currently unused mine will also have a local social impact.***

Design Study ESSvSB (2018-2021)

Call:	H2020-INFRADEV-2017-1
Funding scheme:	RIA
Proposal number:	777419
Proposal acronym:	ESSnuSB
Duration (months):	48
Proposal title:	Feasibility Study for employing the uniquely powerful ESS linear accelerator to generate an intense neutrino beam for leptonic CP violation discovery and measurement.
Activity:	INFRADEV-01-2017

N.	Proposer name	Country
1	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE CNRS	FR
2	UPPSALA UNIVERSITET	SE
3	KUNGLIGA TEKNISKA HOEGSKOLAN	SE
4	EUROPEAN SPALLATION SOURCE ERIC	SE
5	UNIVERSITY OF CUKUROVA	TR
6	UNIVERSIDAD AUTONOMA DE MADRID	ES
7	NATIONAL CENTER FOR SCIENTIFIC RESEARCH "DEMOKRITOS"	EL
8	ISTITUTO NAZIONALE DI FISICA NUCLEARE	IT
9	RUDER BOSKOVIC INSTITUTE	HR
10	SOFIISKI UNIVERSITET SVETI KLIMENT OHRIDSKI	BG
11	LUNDS UNIVERSITET	SE
12	AKADEMIA GORNICZO-HUTNICZA IM. STANISLAWA STASZICA W KRAKOWIE	PL
13	EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH	CH
14	UNIVERSITE DE GENEVE	CH
15	UNIVERSITY OF DURHAM	UK
	Total:	

Very supportive letter from ESS director

The Grant Agreement has to be signed before the 23rd of November 2017 and the project will start 1 January 2018.

ESSvSB will start engaging postdocs soon.

partners: IHEP, BNL, SCK•CEN, SNS, PSI, RAL

NUFACT2017

Uppsala, Sweden

September 25 – 30, 2017

Co-organized by the EuroNuNet

Scientific Program Committee:

A. Blondel, University of Geneva
A. Bogacz, JLAB
A. Bross, FNAL
M. Dracos, IPHC/CNRS
T. Ekelöf, Uppsala University (Chair)
M. Goodman, ANL
D. Harris, FNAL
T. Hasegawa, KEK
P. Huber, Virginia Tech
E. Kemp, UNICAMP
T. Kobayashi, KEK
T. Kosaki, KEK
Y. Kuno, Osaka University
K. Long, Imperial College London
J. Martin, FNAL
H. da Motta, CBPF
T. Nakaya, Kyoto University
J. Nelson, College of William & Mary
M. Olvegård, Uppsala U. (Scient. Secr.)
V. Palladino, INFN Napoli
P. Soler, University of Glasgow
H. A. Tanaka, University of Toronto
F. Terranova, University Milano-Bicocca

Working group conveners:

WG1: Neutrino oscillations
J. Bian, University of California, Irvine
F. Di Lodovico, QMUL
M. Ho, IHEP

WG2: Neutrino Scattering Physics
M. Martini, CEA-Saclay
A. Minamino, Yokohama University
G. Perdue, FNAL

WG3: Accelerator Physics
C. Densham, STFC/RAL
B. Freemire, Northern Illinois University
T. Sekiguchi, KEK/J-PARC

WG4: Muon Physics
R. Craig Group, University of Virginia
M. J. Lee, CAPP, Institute for Basic Science
A. Papa, PSI

WG5: Neutrinos beyond PMNS
W. M. Bonivento, INFN Cagliari
P. Coloma, FNAL
S. Kumar Agarwalla, IOP Bhubaneswar

UPPSALA UNIVERSITET

The 19th International Workshop on Neutrinos from Accelerators

For more information, visit: **https://indico.uu.se/e/nufact2017**

Mats Lindroos' summary of his talk on the ESS linac

- ESS is well into construction and the accelerator project is progressing according to plan towards first beam for target in October 2020
- The ESS facility is built by a collaboration of some 100 research institutes and universities
- Installation has started of cryogenics and for the ion source
- The Accelerator Division is recruiting according to plan and will be ready to take ownership of the accelerator, install it, commission it and enter it into operation
- Most future large scale project are likely to be IK projects and this is a very powerful model. Together we are strongest!

(TE: "IK projects" assumes the full involvement of the AMICI-type EU Technological Infrastructures like STFC, DESY, PSI, INFN, CEA, IN2P3, CERN, IFJ-PAN, KIT & FREIA)

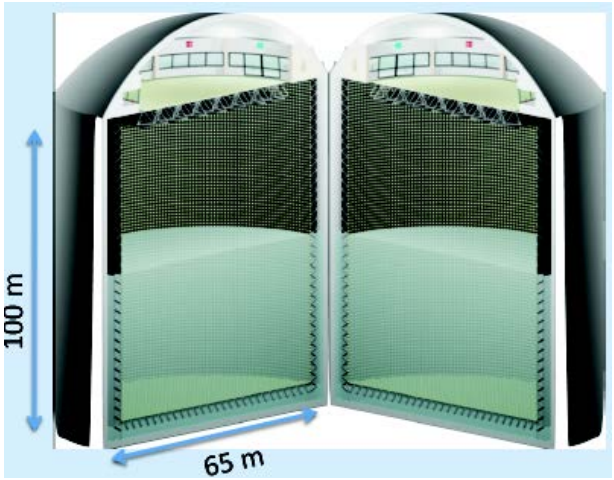
Mamad Eshrai's conclusion of his talk on ESS linac upgrade

- The identified major modifications for the doubling of the beam power via a higher repetition rate and higher beam energy are (in no particular order):
  - Three new electrical substations along the RF gallery.
  - A third main electrical station, alongside the 2 existing ones.
  - HV cable trenches and pulling of additional HV cables from the main station towards the new substations. New HV cables between the substations and the modulators in the RF gallery.
  - Installation of 8 new cryo modules and associated RF stations.
  - Change of klystron collectors, so that 60% more average power can be produced. If klystrons are at the end of their lifetime, they could be exchanged against more powerful models.
  - Installation of additional capacitor chargers to allow faster pulsing of the modulators. This is only possible if the modular design developed in-house is adopted.
  - Installation of a H- source + RFQ + MEBT + beam funnel alongside the existing protons source.
  - Exchange trim magnets and associated power supplies against pulsed versions
- The reviewers, Frank and Eric, did not find any show stoppers for the addition of 5 MW H- acceleration capability in the current state of the ESS linac.

Ref.: Frank Gerigk and Eric Montesinos, CERN-ADD-NOTE-2016-0050

Onoing work on Memphys

The MEMPHYS code for simulation and reconstruction, written within the preceding EUROν project, has been revived and installed on the Iridium cluster at Lund University. A visualisation package, MEMPHYSvis, has been added. It could work on personal devices like mobile phones, tablets, etc. that makes it appealing for use outside of the experimental physics neutrino community.



A virtual machine has been set up and open for download and use by the members of the WG. It contains all the necessary libraries and specific to Detectors WG code so that a newcomer could download it and start working without the painful process of setting up the relevant software environment.

The MEMPHYS code has been tried by Peter Christiansen for setting up simulation of the water Cherenkov Near detector. Useful experience has been gained.

Garpenberg Research Infrastructure Project for Neutrinos (GRIPnu)

http://www.physics.uu.se/digitalAssets/374/c_374310-l_1-k_gripnu-english-version.pdf

A Socio-economic and Industrial Study of the Consequences of constructing a World-leading Neutrino Detector in Garpenberg in Region Dalarna commissioned by Garpenberg Council

Translated from Swedish by Colin Carlile, Uppsala University March 2017

Summary Description of the GRIPnu project

Project Leader: Hedemora Enterprise AB

Geography: North Central Sweden, Skåne-Blekinge and East Central Sweden

Type of project: National Regional funds programme, Investment Priority 1b

The national strategy for ESS, the European Spallation Source, indicates that the very significant investment in international research infrastructures that is taking place in southern Sweden will also be reflected more widely within Sweden. The GRIPnu project enables the ESS venture to add a second node which would have significant positive effects in central Sweden, and enable contacts to be established between both academia and industry. The ESS accelerator will be the world's most powerful accelerator with a beam power of 5 MW. A European research consortium ESSnuSB, within the framework of the EU COST Action, has been active since 2012, planning an ambitious world-leading research project on neutrinos, which is based upon the use of the ESS accelerator in Lund, and within which the FREIA Laboratory in Uppsala, currently is strongly committed.

Table of Contents

EU satsar 30 miljoner på Garpenbergsgruvan

HEDEMORA Kan Garpenberg bli en internationell forskningsstation om neutriner?

Ja, möjligheten finns och har ökat. EU har nyligen beslutat att skjuta till 30 miljoner kronor för att se om det går att bygga en neutrinodetektor nere i gruvan.

– Det är mycket glädjande, säger Tord Ekelöf, projektledare vid Institutionen för fysik och astronomi vid Uppsala universitet.

Tidningen har tidigare berättat att det pågår ett arbete för att se om det går att göra om delar av gruvan till en stor forskningsanläggning.

Det pågår diskussioner om att bygga neutrinodetektorer på ett fåtal platser i världen. I Europa ligger Garpenberg längst framme, men USA eller Japan kan hinna före.

Det pågår diskussioner om att bygga neutrinodetektorer på ett fåtal platser i världen. I Europa ligger Garpenberg längst framme, men USA eller Japan kan hinna före.

FOTO: KJELL JANSSON

Anledningen till att Garpenbergsgruvan har kommit på tal är att den ligger på rätt avstånd från Lund. Och i Lund byggs materialforskningsanläggningen ESS (European Spallation Source). När den är klar ska forskarna få fram neutroner med hjälp av en stor accelerator. ESS väntas vara i full drift år 2025.

Tord Ekelöf, och en rad andra europeiska forskare, tror att ESS även kan användas för att få fram de mycket mindre partiklarna neutriner.

– En neutrino är en riktig elementarpartikel och har en miljard gånger mindre massa än en neutron. En neutron stoppas av ett stenblock, men en neutrino kan gå genom hela jorden utan att hejdas, säger Tord Ekelöf.

Tanken är att forskarna ska skicka en mycket intensiv stråle med neutriner från Lund till Garpenberg. På 1000 meters djup ska det, enligt planen, göras ett hålrum på en miljon kubikmeter, 100 meter högt och 100 meter brett. Det ska fyllas med renat vatten och när neutrinon stöter på en atomkärna i vattnet kan den omvandlas till en laddad partikel, till exempel en elektron, vilket leder till att en ljusblixt sänds ut.

För att kunna detektera ljusblixtarna och därmed neutrinon ska det sättas upp ett stort antal ljusdetektorer på bergväggarna.

– Att bygga det här är en väldig utmaning. Det är ingen lätt uppgift att beräkna hur det ska se ut, säger Tord Ekelöf.

Universiteten i Lund och Uppsala, KTH i Stockholm och tekniska universitetet i Luleå är inblandade i projektet, totalt är det 15 europeiska universitet och laboratorier som är med.

Tillsammans ska de göra en "designstudie", där det undersöks om det går att skapa en neutrinodetektor i Garpenberg. Studien kommer att ta fyra år. Efter det behövs ytterligare en studie för att se hur det ska förverkligas tekniskt, den väntas ta tre år.

När det är klart tar det sju år att bygga detektorn. Så tidsperspektivet är att den kan vara i gång framåt år 2032. Pengarna som EU beviljade i augusti, ska bland annat gå till att anställa åtta nyexaminerade forskare och ett flertal doktorander.

Stödet som EU nu ger via forskningsfonden Horizon 2020 går till den första delstudien, men för att bygga anläggningen krävs hela sju miljarder kronor.

"En neutrino är en riktig elementarpartikel och har en miljard gånger mindre massa än en neutron. En neutron stoppas av ett stenblock, men en neutrino kan gå genom hela jorden utan att hejdas."
Tord Ekelöf

Tord Ekelöf, projektledare, är här 1059 meter under marken i Garpenbergsgruvan.

– Det kan inte Sverige betala själv. Man måste nå en europeisk finansiering ungefär som för ESS, säger Tord Ekelöf.

Han hoppas att provborrningarna ska kunna påbörjas nere i Garpenbergsgruvan under 2018.

Inger Wilstrand, vd för Hedemora näringsliv, tycker att det är positivt att EU skjuter till pengar.

– Det visar, som jag ser det, att det har legitimitet i EU-kretsen, säger hon.

Lokalt arbetas det för att få fram pengar till provborrningarna. Tidigare har det sagts att det krävs en miljon kronor per borrhål och ett 15-tal hål behöver borras.

Om det byggs en neutrinodetektor så får det många positiva effekter, tror Wilstrand.

– Det skulle vara attraktivt för länet och dess företag och öka besöksnäringen eftersom det skulle komma forskare från hela världen, säger Inger Wilstrand.

Text
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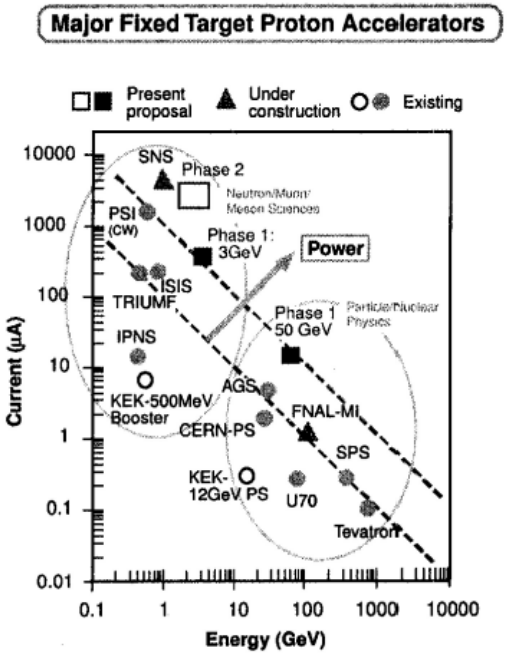
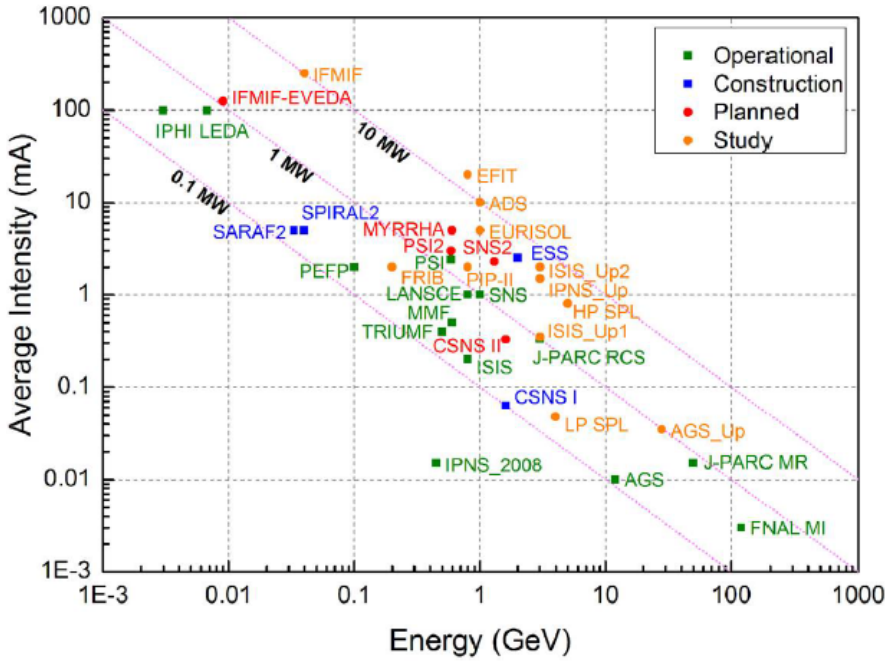
A slide from Mauro Mezzeto's Future Outlook talk at NUFACT2017

Proton drivers

Year 2000



Year 2017, Talk of C. Plostinar



Where do we go from here?

The ESSnuSB technically limited time schedule:
2018-2021 Design Study -> Conceptual Design Report
2021-2023 Preparatory Phase -> Technical Design Report
2024-2030 Build-up of ESSnuSB
2031-2040 Data taking -> CP angle and other measurement
To this must be added the extra time, less straightforward to estimate, of political negotiations which will in any case imply the need for a least a few more years

In order to get EU financing 2021 for the Preparatory Phase we need to deliver convincing Design Study results by latest autumn 2019 as input to the CERN Strategy Council preparation of its input to the ESFRI update in 2020

This leaves us only from autumn 2027 to autumn 2019, 2 years, to achieve sufficient progress to convince the CERN Strategy Council to recommend us for being included on the ESFRI list.

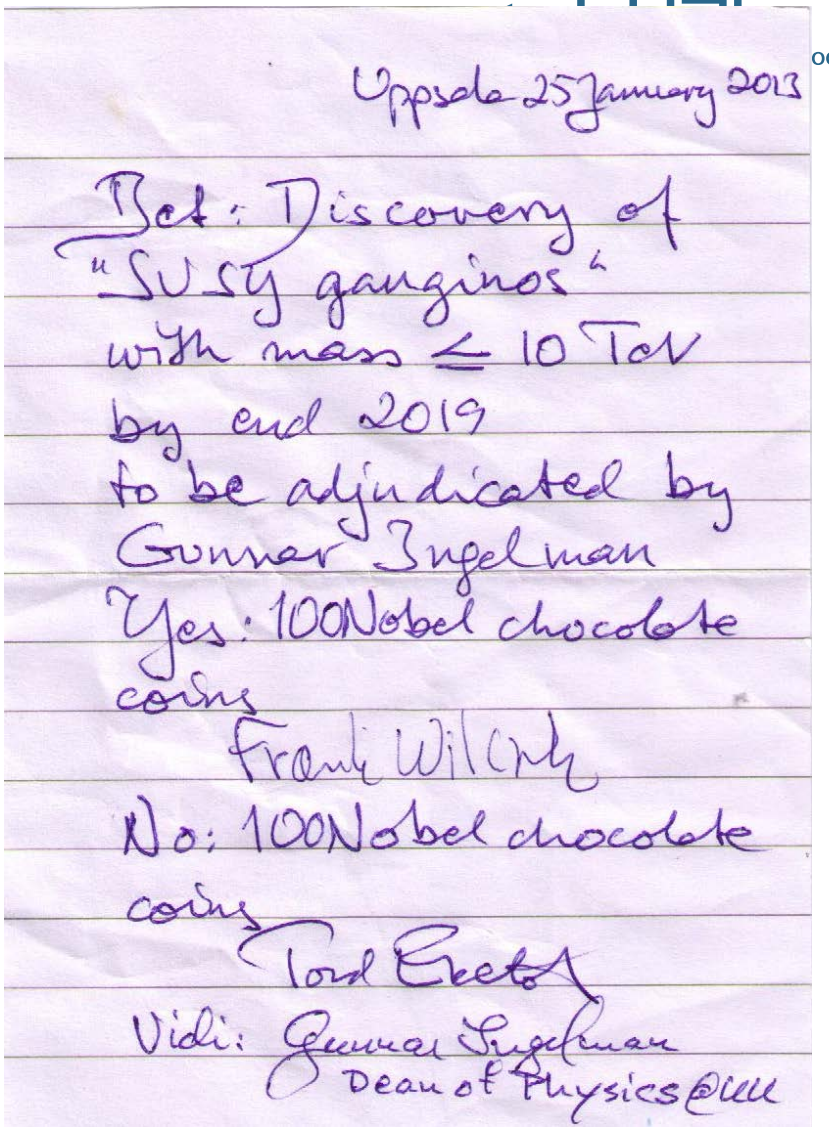
Conclusions

- The large ν detector has a rich astroparticle and p lifetime program.
- Significantly better CPV sensitivity at the 2nd oscillation maximum.
- The European Spallation Source Linac will be ready in less than 8 years (5 MW, 2 GeV proton beam by 2023).
- ESS will have enough protons to go to the 2nd oscillation maximum and increase its CPV sensitivity.
- CPV: 5 σ could be reached over 60% of δ_{CP} range (ESSνSB) with large potentiality.
- **EU COST network project supports ESSνSB**
- **EU/H2020 has decided to finance an ESSνSB Design Study project which will start 1 January 2018.**

In view of the next talk on the program:

Betting on the Higgs bosonen and on Supersymmetri

Wilczek - Conrad bet
2012 on the Higgs boson



Wilczek – Ekelöf bet
2019 on SUSY gauginos