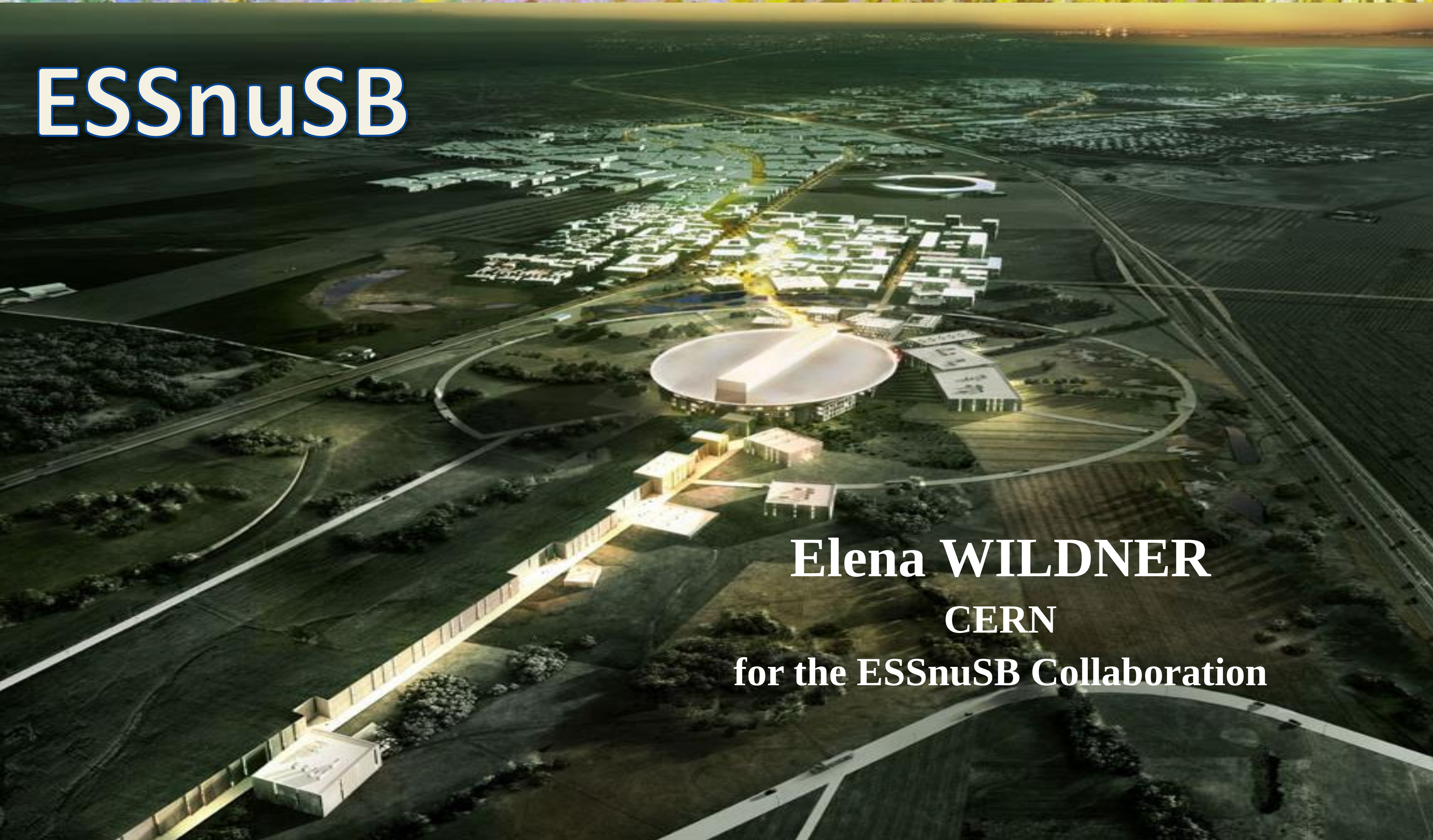
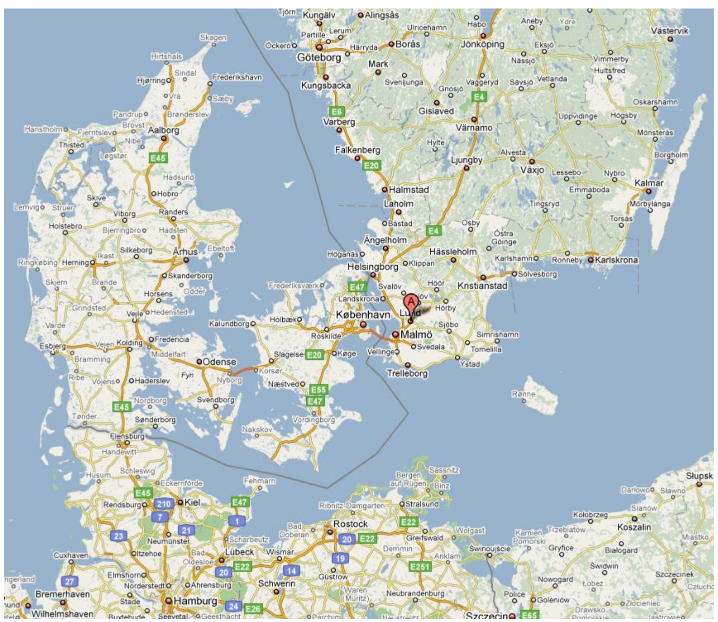
ESSnuSB



Elena WILDNER
CERN
for the ESSnuSB Collaboration

The European Spallation Source (ESS)

- ESS is a neutron spallation source that is being built by a collaboration of 17 European countries.
- ESS is located in southern Sweden (Lund)



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

The linac tunnel on 10 april 2015

EUROPEAN SPALLATION SOURCE

ESS as proton driver for spallation

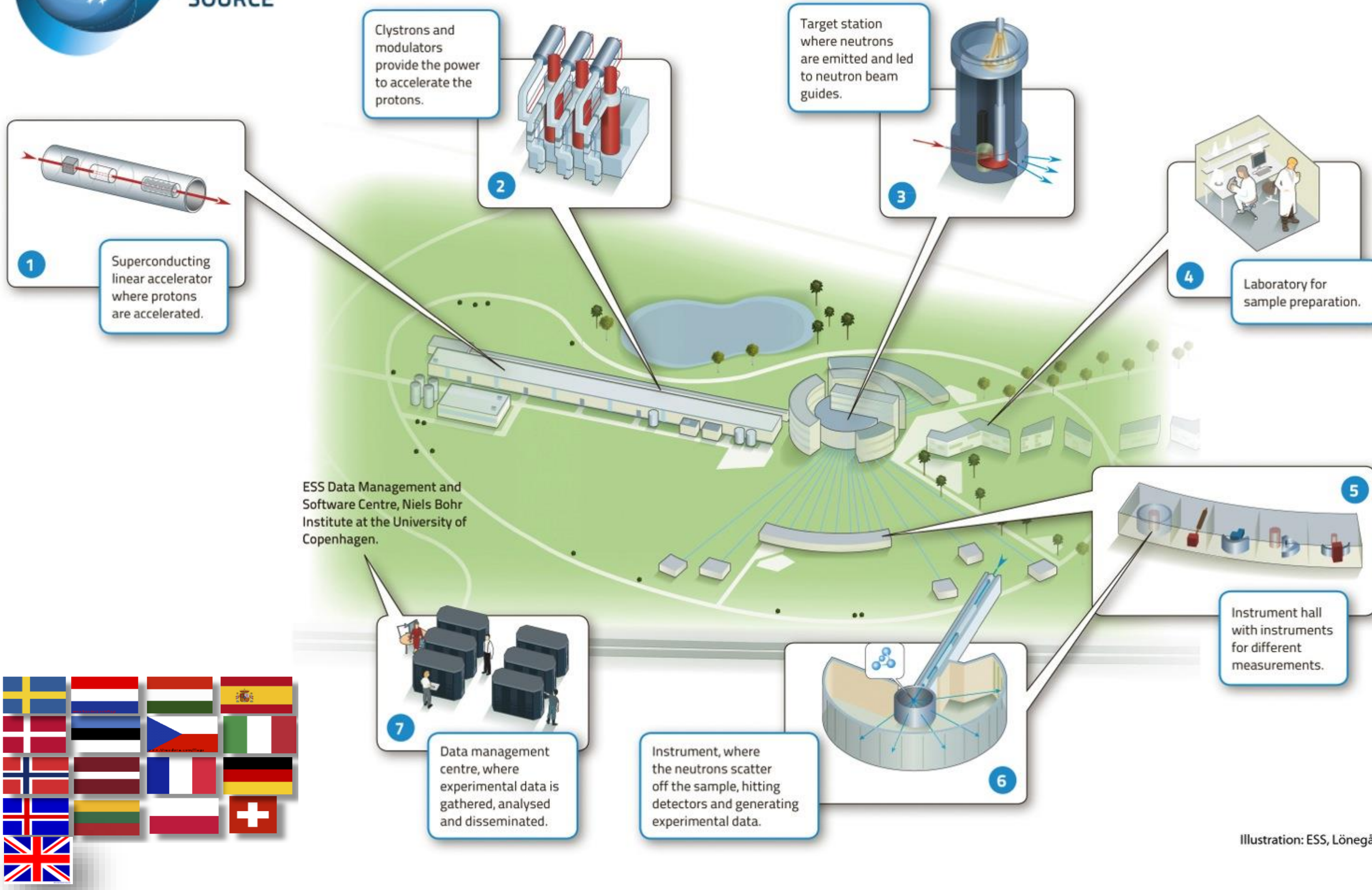
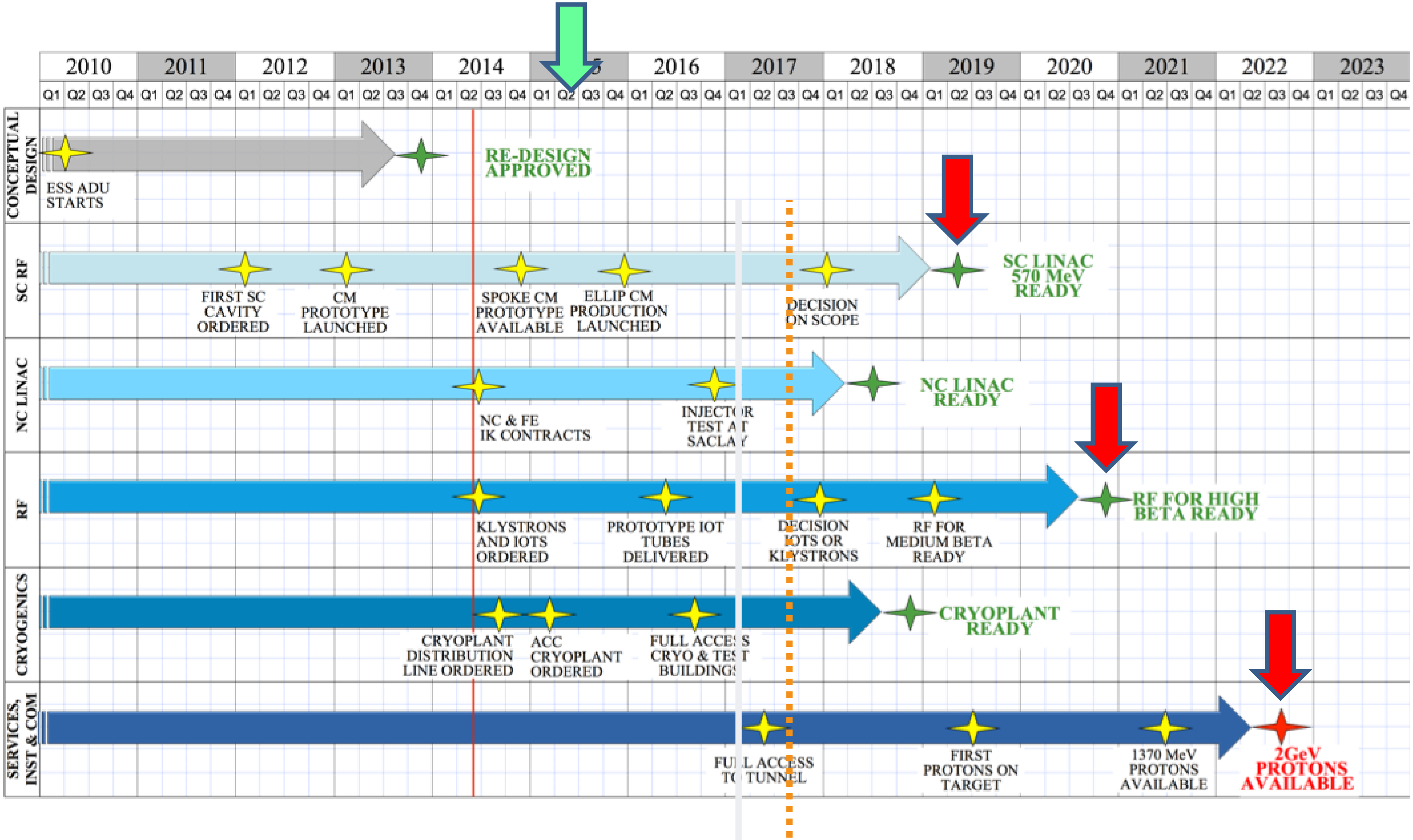
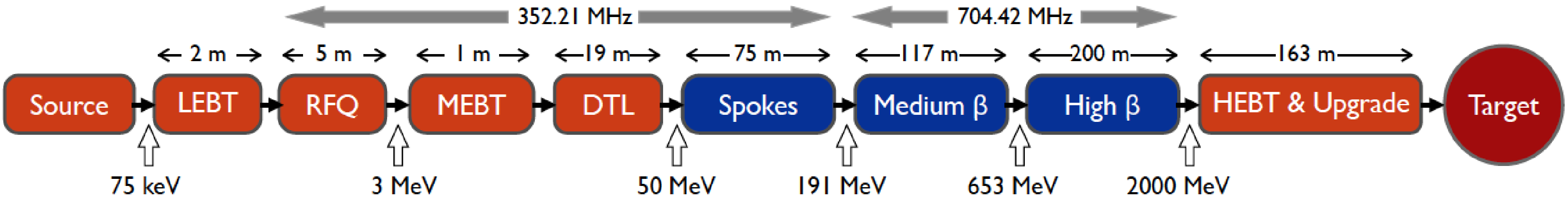


Illustration: ESS, Lönegård

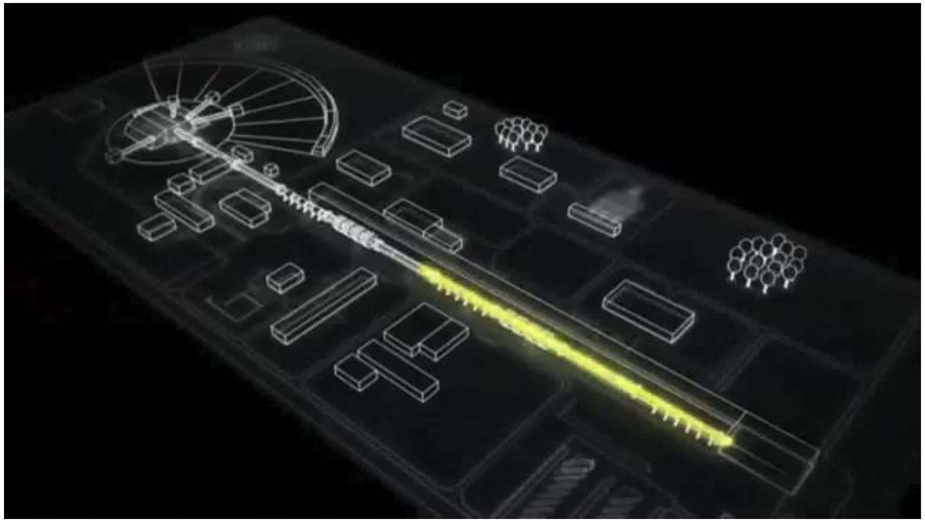
ESS LINAC PROJECT SCHEDULE



ESS 5MW proton linac



- The ESS will be a copious source of spallation neutrons
- 5 MW average beam power
- 125 MW peak power
- 14 Hz repetition rate (2.86 ms pulse duration, 10^{15} protons)
- 2.0 GeV protons (up to 3.5 GeV with linac upgrades)



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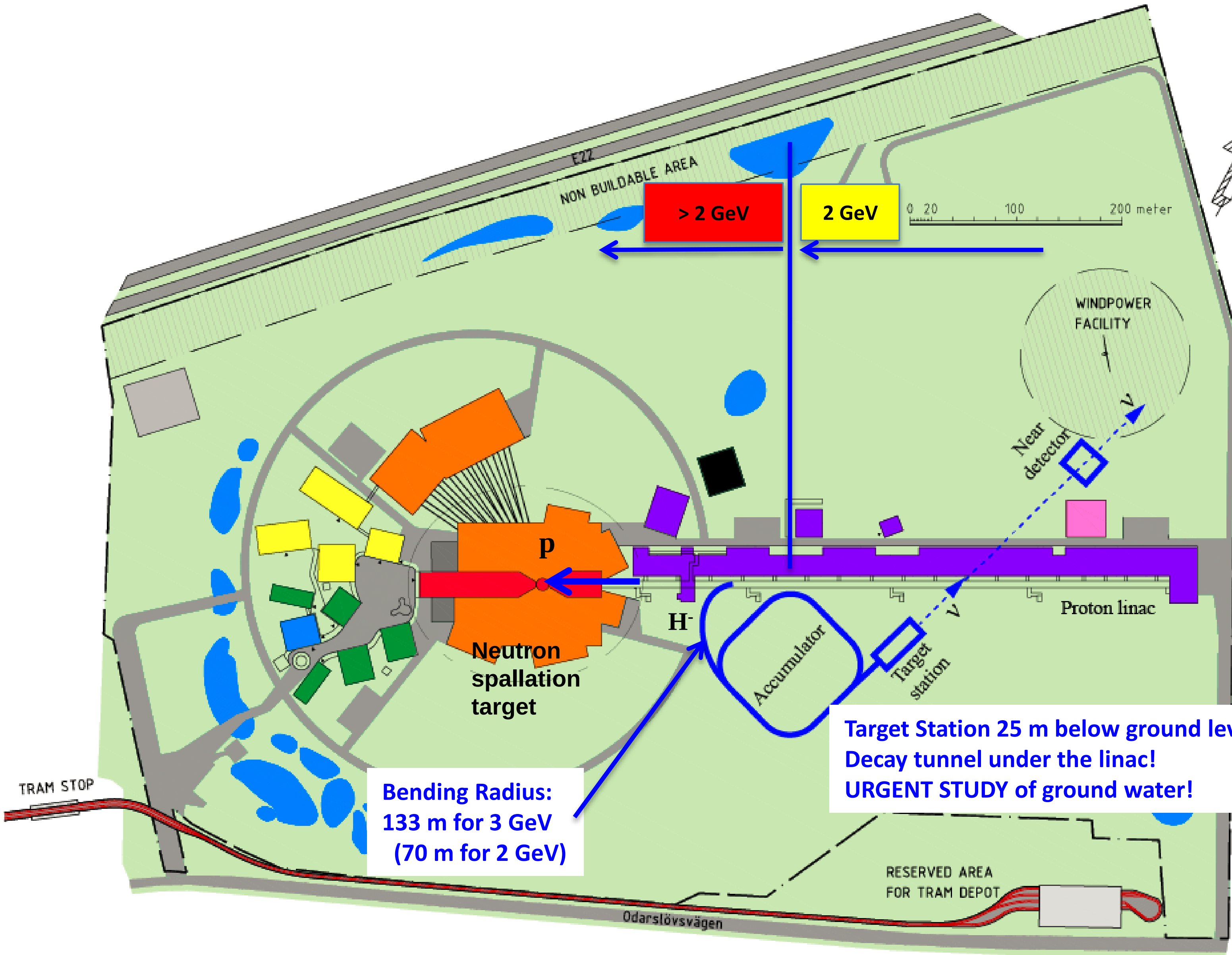
http://europeanspallationsource.se/documentation/tdr.pdf

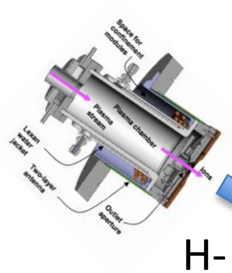
ESSnuSB on ESS site

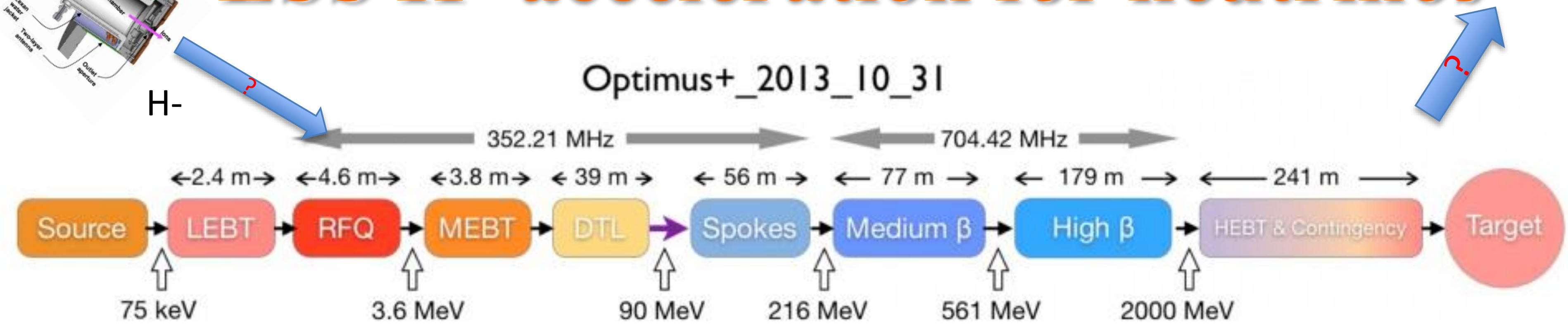


Bending Radius:
133 m for 3 GeV
(70 m for 2 GeV)

Target Station 25 m below ground level
Decay tunnel under the linac!
URGENT STUDY of ground water!

ESS H- acceleration for neutrinos

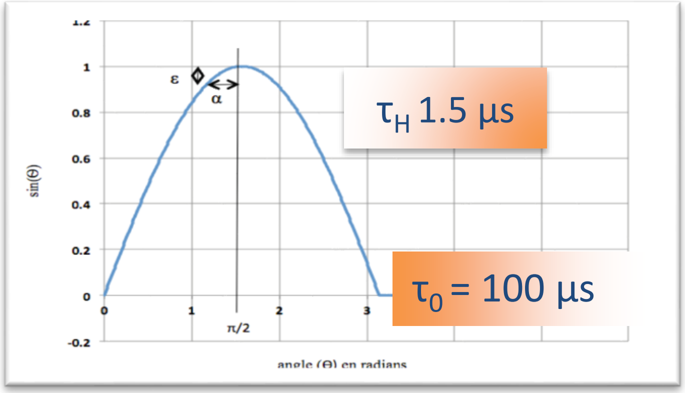




- The ESS linac for neutron spallation: proton acceleration 14 Hz
- Duty factor low (4%); some additional capacity is available
- Repetition rate can be increased to permit extra acceleration cycles (total power of extra cycles 5 MW)
- **ESS would accelerate in total 10 MW!**
- Charge in the accumulator 1.1 10^{15} protons 2 GeV, big challenge
- **>2.7x10^{23} 2 GeV p.o.t/year**

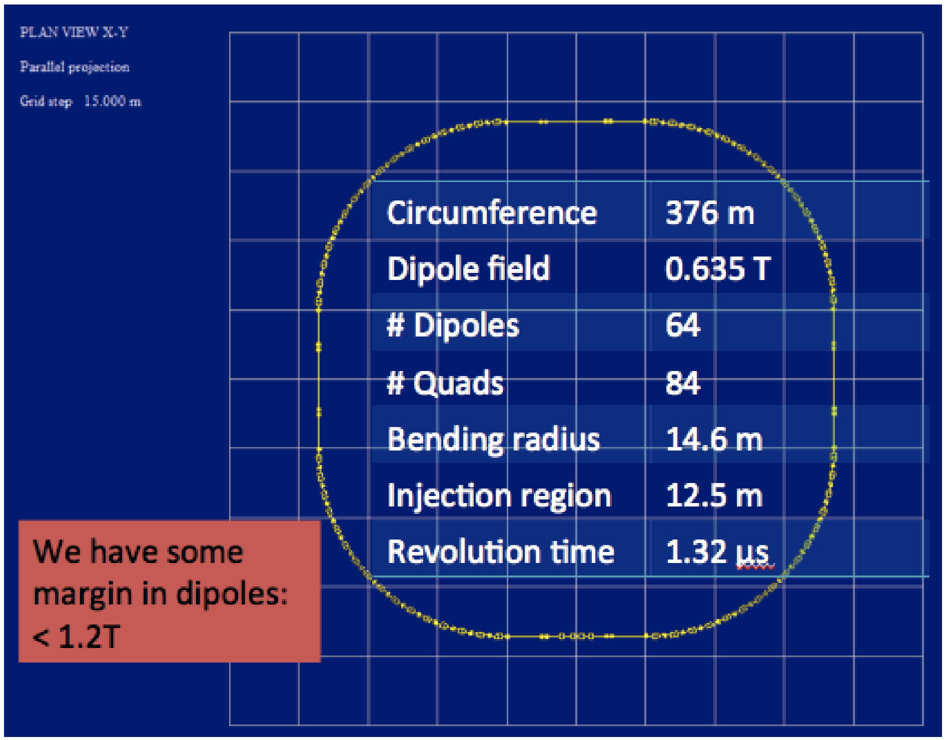
ESS Accumulator for neutrino production

- **Constraints on present neutrino target focusing system: short pulses**



- Solution: **reduce beam pulse length:**
  - Shorten the linac pulse by accumulating the linac beam
- **Accumulator constraints**
  - Reasonably-sized accumulator ring circumference and apertures
  - Multiturn injection of high intensity linac beam: we need H-
  - High intensities may cause collective effects and beam loss

ESS Accumulator for neutrino production (II)



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

We have some margin in dipoles: < 1.2T

Accumulator lattice based on Spallation Neutron Source, Oak Ridge

Layout optimization and beam dynamics

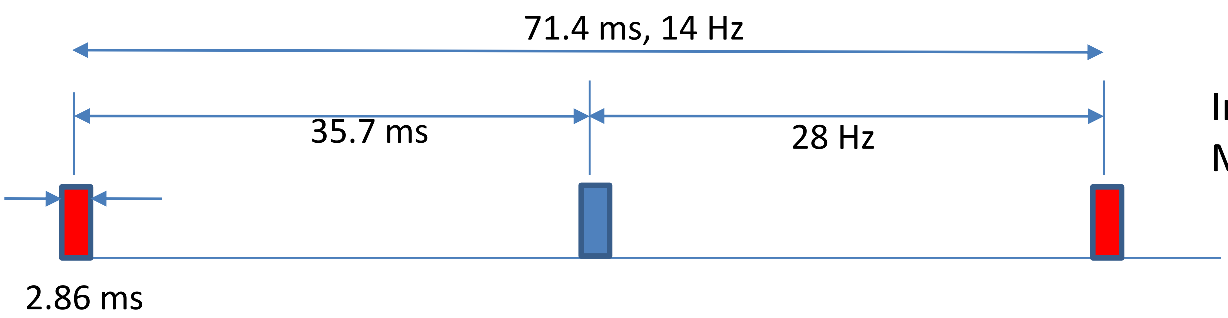
Transfer lines and extraction of beam from linac

Switchyard

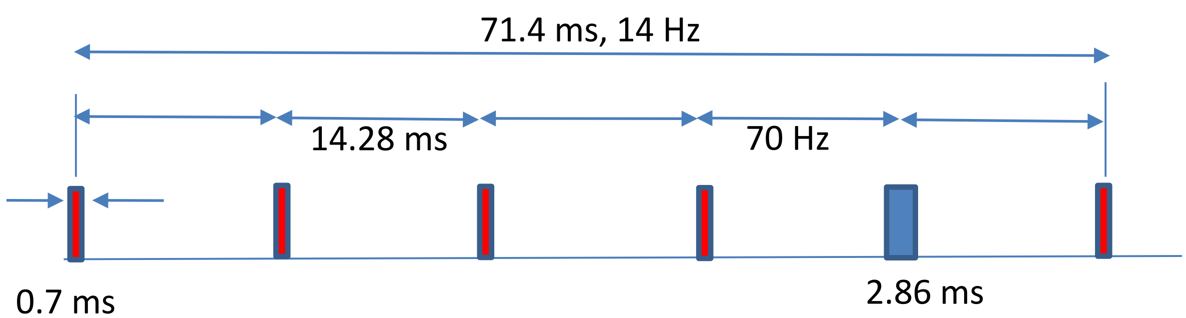
Linac Pulsing, options

Neutrino (H- -pulse)

Neutron (proton pulse)



Insert one H- pulse 28 Hz
May need several accumulators



Mitigation of charges in accumulator: shorter pulses, higher pulsing requency of linac.

Implies some overhead (cavity filling)

The Linac has to be upgraded

Cost Impact	Per modulator	Total (45 modulators)
1)- Adding extra capacitor charger modules	+ 60 kEURO	+ 3 MEURO
2)- Re-winding HVHF transformers and output filter inductors	+ 100 kEURO	+ 4.5 MEURO
3)- Labour costs (contract follow-up, testing, etc.)		+ 5 MEURO
Total cost increase for modulators' upgrade		**+ 12.5 MEURO (+ 3**

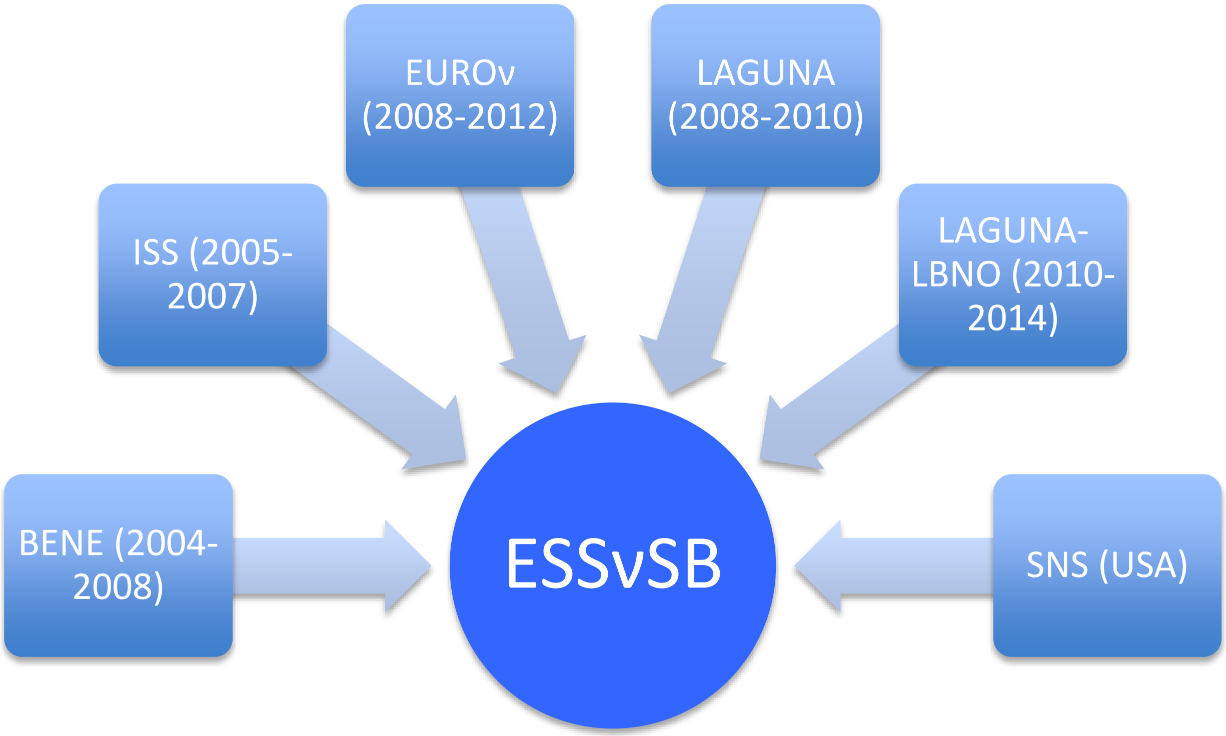
Footprint Impact	Per modulator	
Footprint required for additional capacitor chargers	~ 1.2m x 1m	

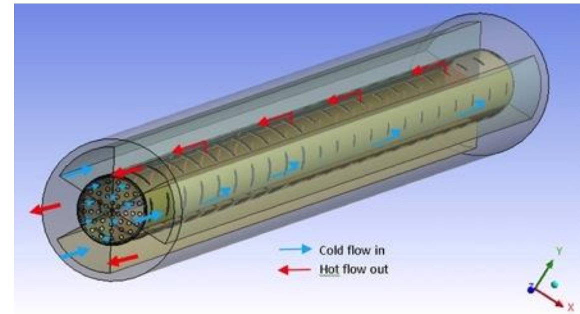
Cost Impact		Total (45 modulators)
1)- Add additional 10kV/600V distribution transformers (doubling the total quantity, keeping existent ones)		+ 2 MEURO
2)- Add additional LV power cables and switchboards (doubling the total quantity, keeping existent ones)		+ 1.5 MEURO
3)- Labour costs (contract follow-up, testing, etc.)		+ 2 MEURO
Total cost increase for AC grid upgrade *(only for LV grid; new buildings and CF expenses not included)*		**+ 5.5 MEURO (+ 100%)**

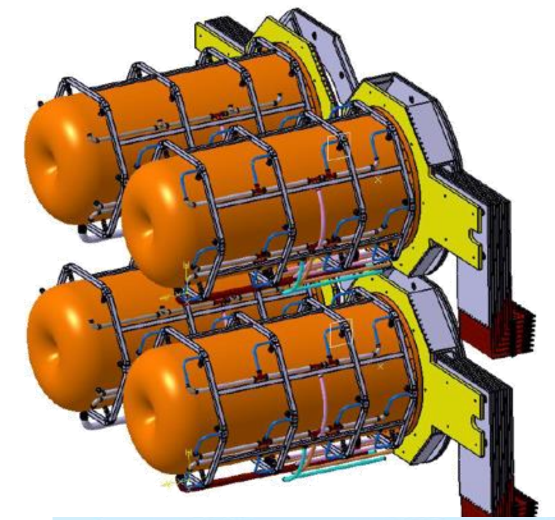
Other impacts (to CF)		
New buildings will be required for extra LV transformers and swichboards; Double footprint required.		
An additional HV 120kV/10kV power transformer will be required		
All HV distribution lines and protection devices at 120kV and 10kV levels will be doubled		

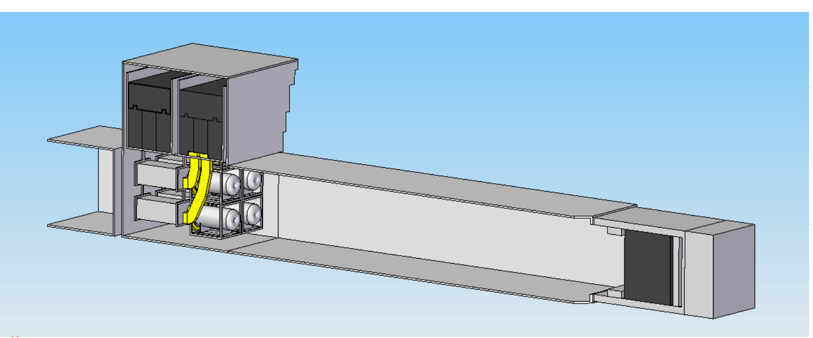
To be prepared for preferably at an early stage
List of need prepared and taken into consideration by the accelerator division
Some options already built in
Infrastructure upgrades are important to plan for

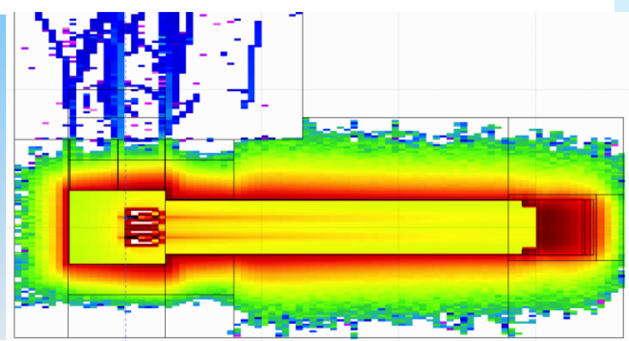
Existing Expertise

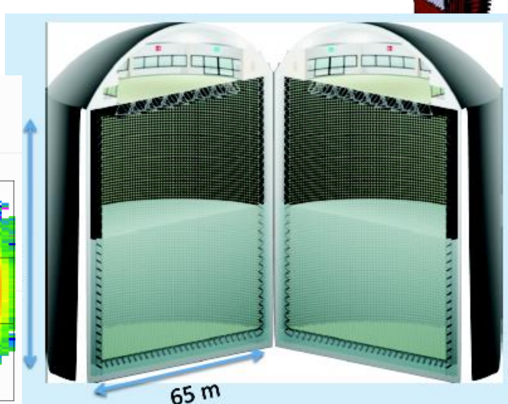




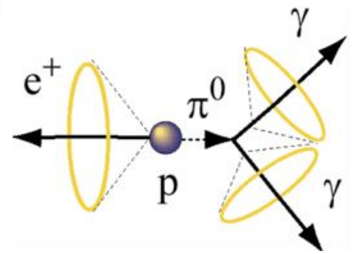




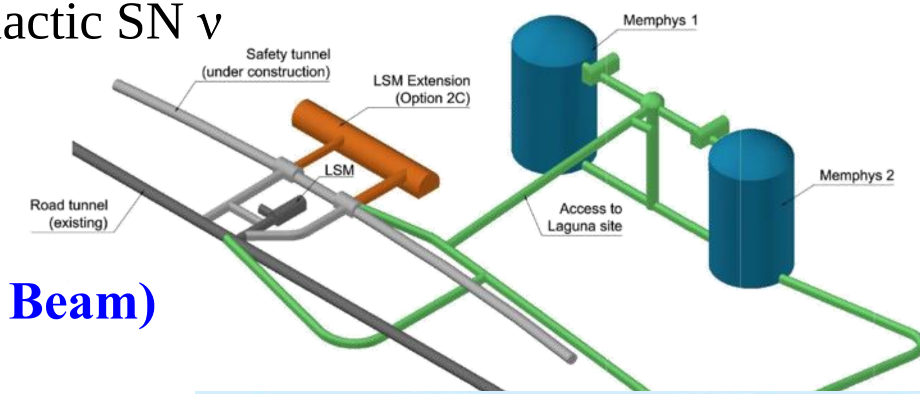




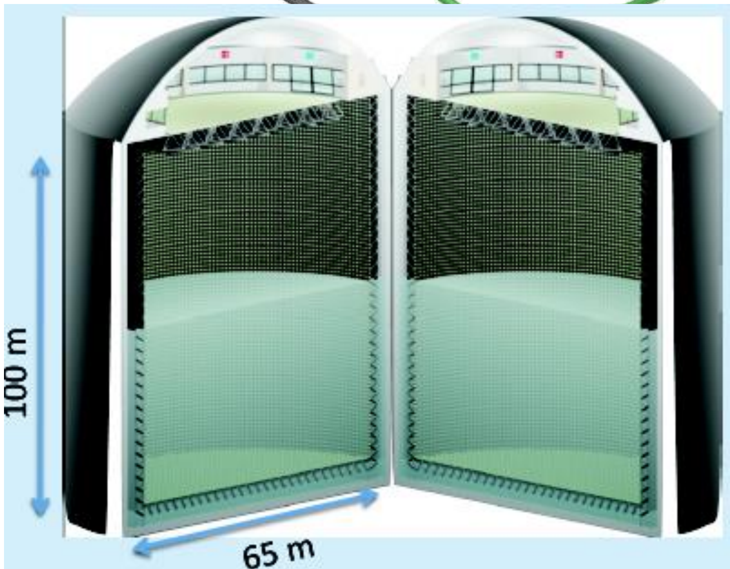
The MEMPHYS WC Detector
(MEgaton Mass PHYSics)



- **Proton decay**
- **Astroparticles**
- Understand the gravitational collapsing: galactic SN ν
- Supernovae "relics"
- Solar Neutrinos
- **Neutrino Oscillations (Super Beam, Beta Beam)**
- Atmospheric Neutrinos

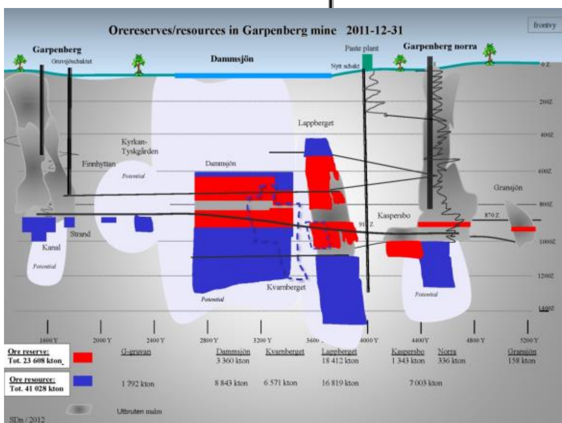


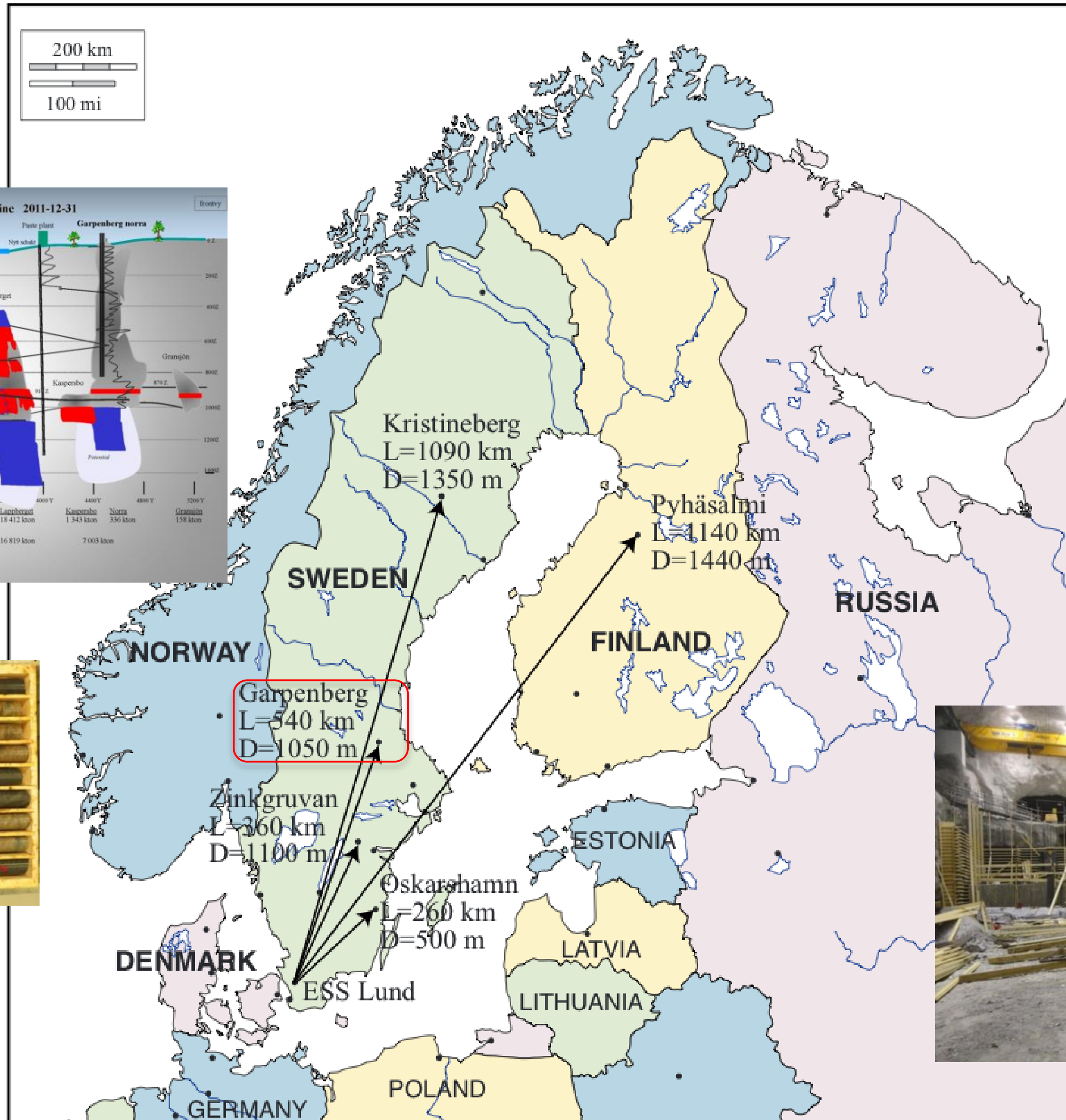
- 500 kt fiducial volume (~20xSuperK)
- Readout: ~240k 8" PMTs
- 30% optical coverage



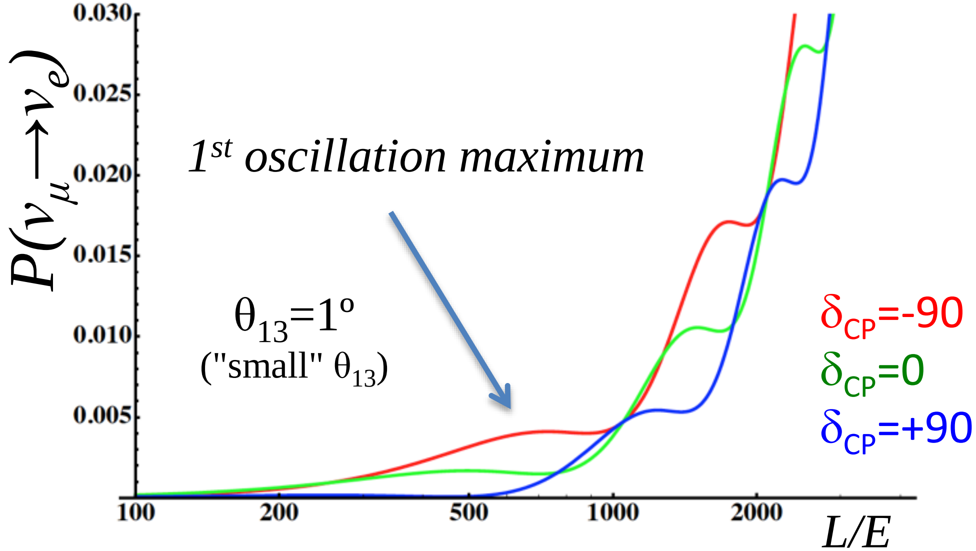
(arXiv: hep-ex/0607026)

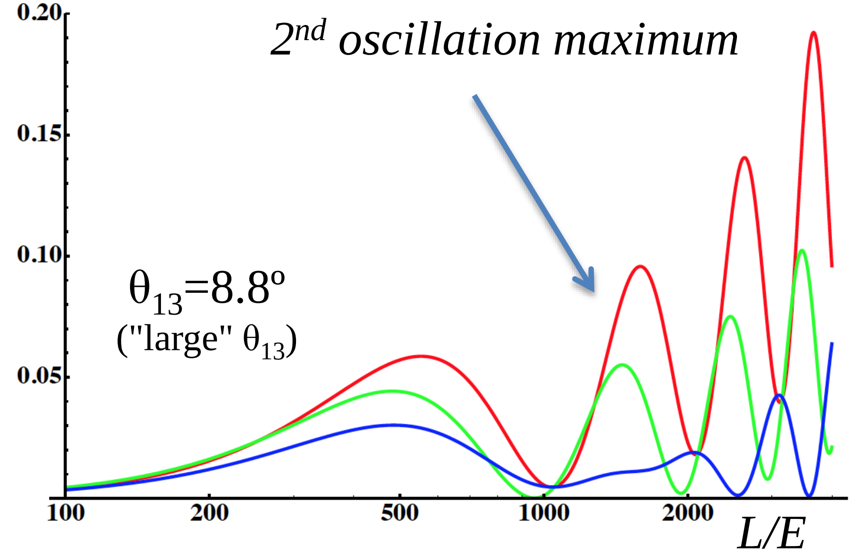
Possible locations for far detector





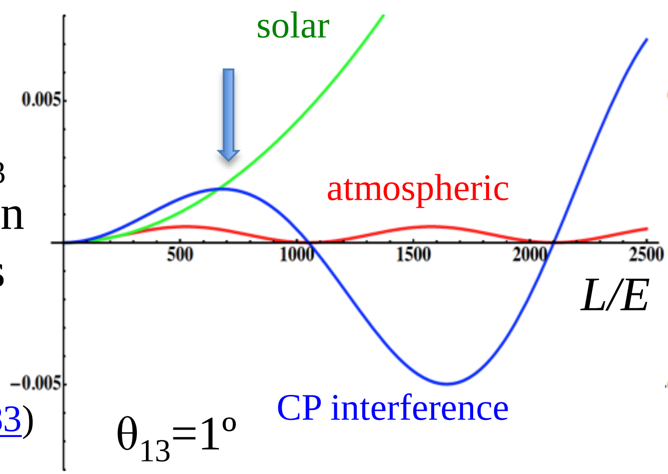
Neutrino Oscillations with "large" θ_{13}

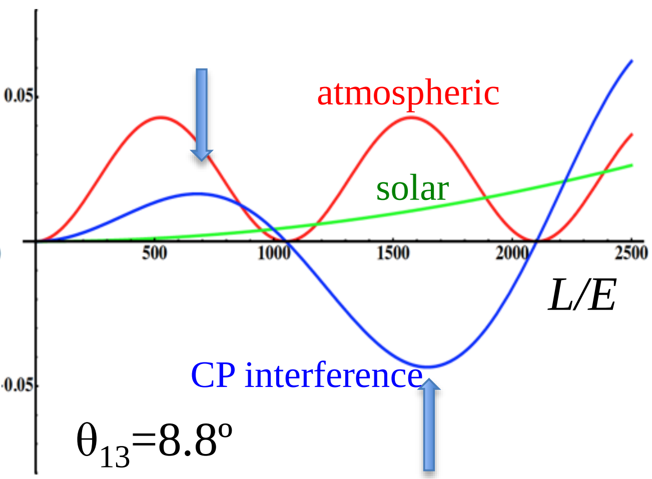




for small θ_{13}
1st oscillation maximum is better

(arXiv:1110.4583)





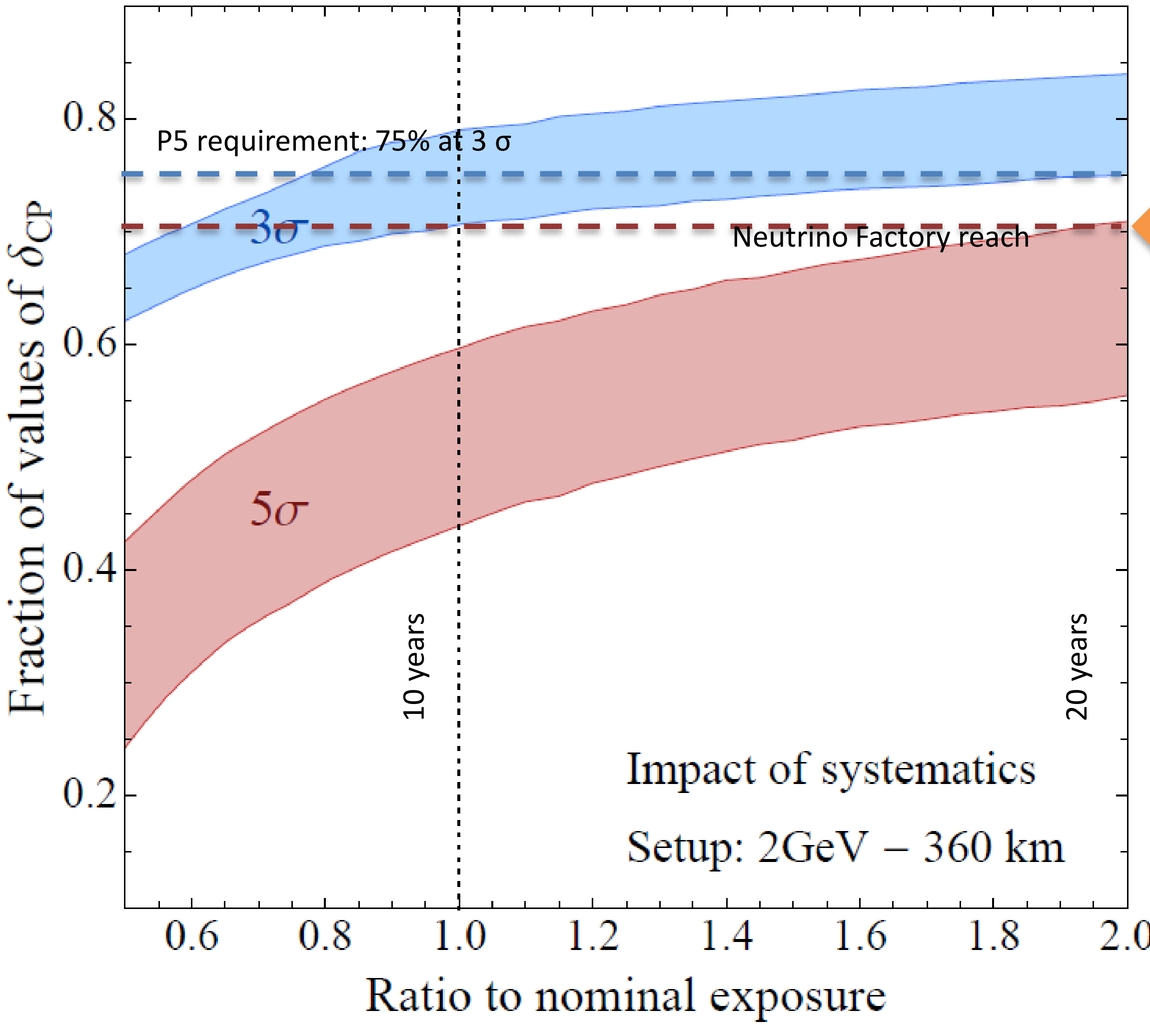
for "large" θ_{13}
1st oscillation maximum is dominated by atmospheric term,

- 1st oscillation max.: $A=0.3\sin\delta_{CP}$
- 2nd oscillation max.: $A=0.75\sin\delta_{CP}$

more sensitivity at 2nd oscillation max.
(see arXiv:1310.5992 and arXiv:0710.0554)

Systematic errors and exposure

for ESSnuSB systematic errors see 1209.5973 [hep-ph] (lower limit "default" case, upper limit "optimistic" case)



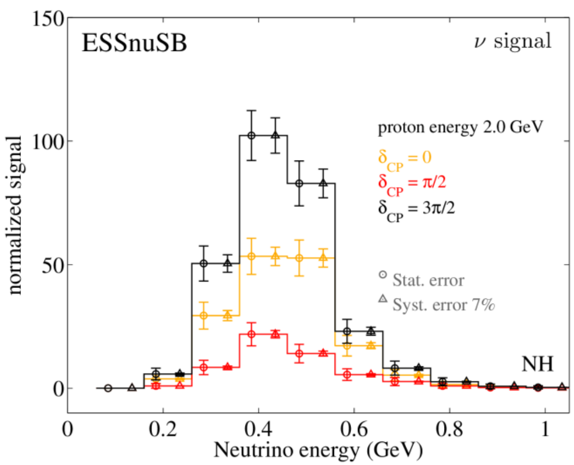
High potentiality

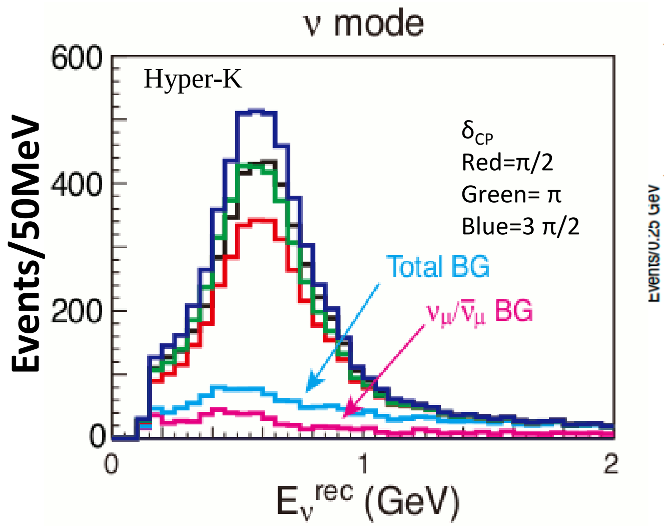
60% of the δ_{CP} range could be reached to at least 5 σ

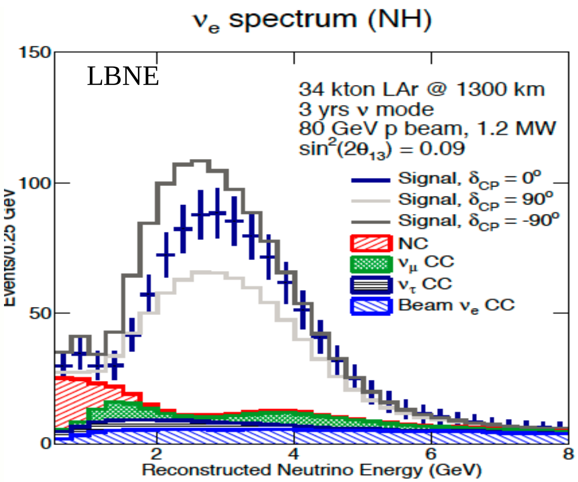
(courtesy P. Coloma)

The sensitivity of the neutrino energy distribution to δ_{CP}

ESSnuSB second maximum | Hyper-K first maximum | LBNE first maximum



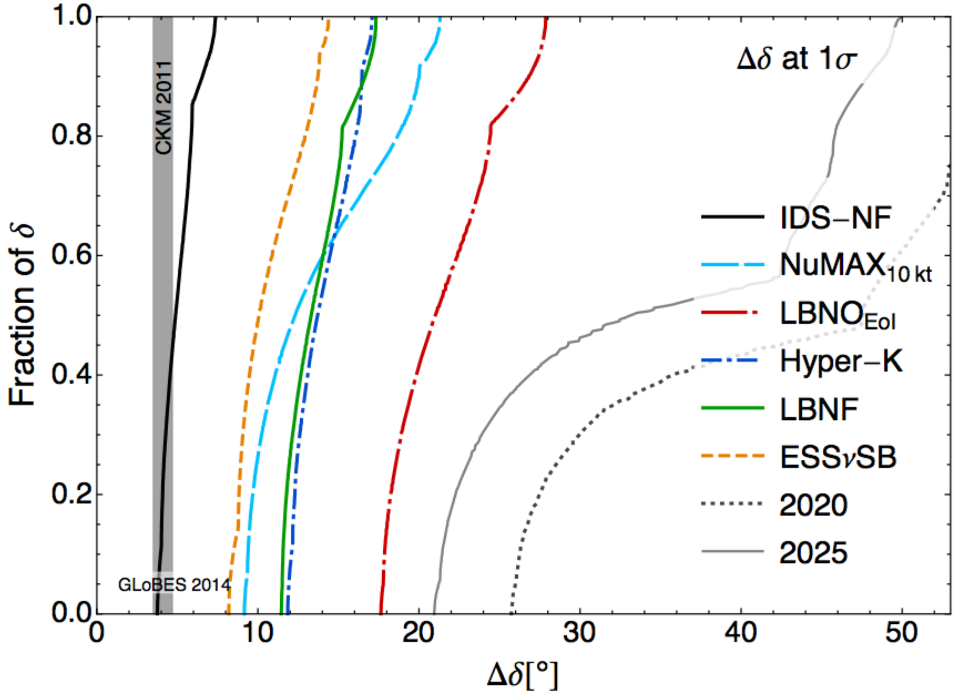


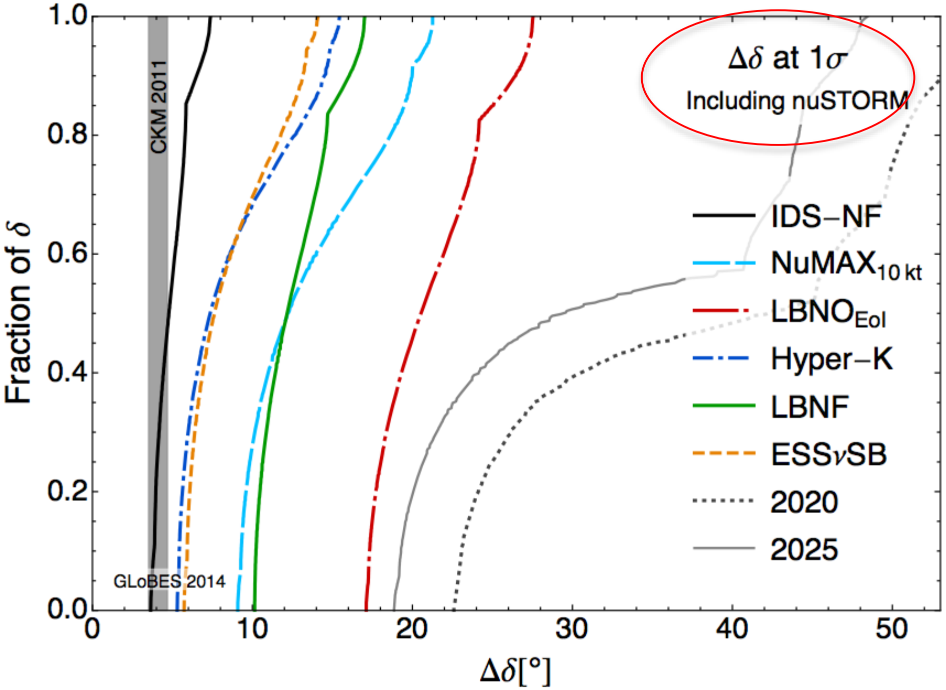


Relative difference in counts at maximum between δ_{CP} = 3π/2 and π/2 :

105/22 = 4.8 | 510/340 = 1.5 | 110/65 = 1.5

Results including nuSTORM





LBNF (40 kton detector, 1.2MW beam power)

Systematics are basically the same as before. nuSTORM plots assume that cross sections are determined at the 1% level of precision, removing the constraint between the cross sections for different flavors, they are all allowed to vary independently in the fit.

Pilar Coloma et al.

ESS Neutrino Super Beam

Available online at www.sciencedirect.com
ScienceDirect
Nuclear Physics B 885 (2014) 127–149
NUCLEAR PHYSICS B
www.elsevier.com/locate/nuclphysb

A very intense neutrino super beam experiment for leptonic CP violation discovery based on the European spallation source linac

E. Baussan[m], M. Blennow[l], M. Bogomilov[k], E. Bouquerel[m], O. Caretta[c], J. Cederkäll[f], P. Christiansen[f], P. Coloma[b], P. Cupial[e], H. Danared[g], T. Davenne[c], C. Densham[c], M. Dracos[m,*], T. Ekelöf[n,*], M. Eshraqi[g], E. Fernandez Martinez[h], G. Gaudiot[m], R. Hall-Wilton[g], J.-P. Koutchouk[n,d], M. Lindroos[g], P. Loveridge[c], R. Matev[k], D. McGinnis[g], M. Mezzetto[j], R. Miyamoto[g], L. Mosca[i], T. Ohlsson[l], H. Öhman[n], F. Osswald[m], S. Peggs[g], P. Poussot[m], R. Ruber[n], J.Y. Tang[a], R. Tsenov[k], G. Vankova-Kirilova[k], N. Vassilopoulos[m], D. Wilcox[c], E. Wildner[d], J. Wurtz[m]

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arXiv:1212.5048
arXiv:1309.7022

14 participating institutes from 10 different countries, among them ESS and CERN

EU H2020 Design Study application has been submitted recently !

When and to what price ?

- Total price of ESSnuSB including the detector is 1.2 BEUR:
  - 100 MEUR linac
  - 200 MEUR accumulator
  - 200 MEUR target station
  - 700 MEUR the far detector

- If we have our CDR in 2018 and if we convince everybody to build this facility, we could start construction at the moment when the neutron facility will be ready, i.e., 2023. The construction of the neutrino facility could be completed 2030 when we will be able to start data taking.

Conclusions

- CP Violation intense neutrino beams are needed
  - Profit of the worlds most powerful linac ar ESS
- Better CPV sensitivity at the 2nd oscillation maximum (theta13 rel. large)
  - Mines available at a good distance
- ESS will have enough protons to go to the 2nd oscillation maximum increasing the sensitivity to CPV.
- The European Spallation Source Linac will be ready in less than 10 years
- CPV: 5 σ could be reached over 60% of δ_{CP} range (ESSνSB)
- Full complementarity with a long baseline experiment on the 1st oscillation maximum using a LAr detector.
- A feasibility Design Study for ESSnuSB has now to be made
  - Collaborators are welcome: experiment, detector, physics, accelerator