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ESS NEUTRINO SUPER BEAM

Optimization of the Target Station for the ESSνSB Project Using the Genetic Algorithm

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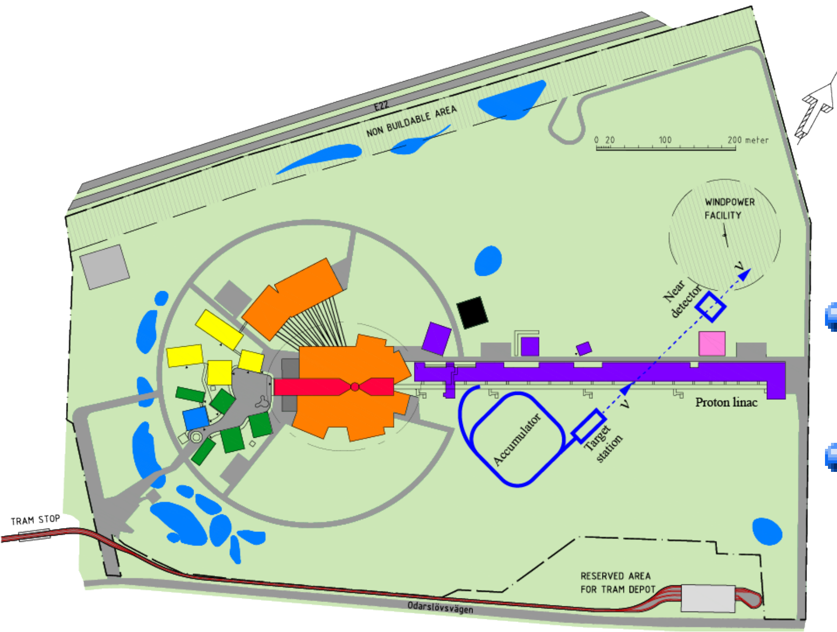
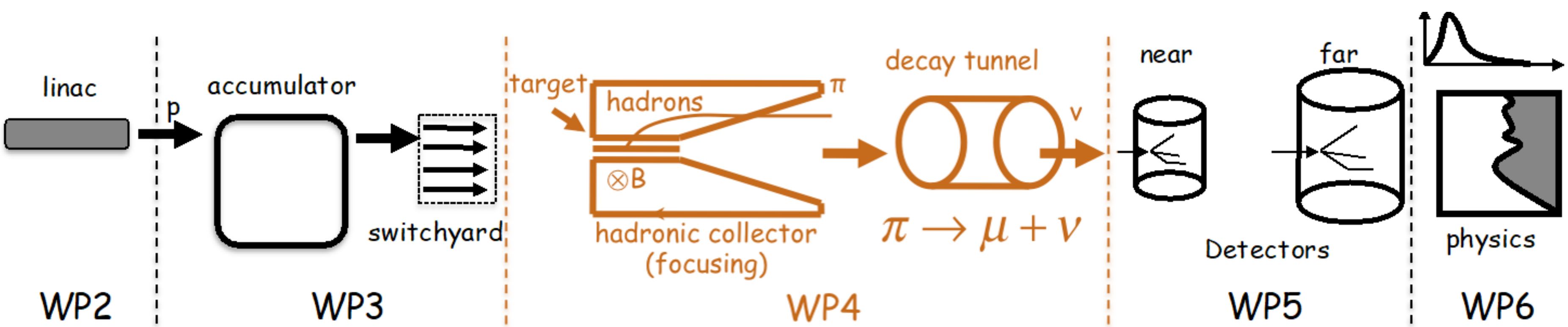
The ESSνSB Project



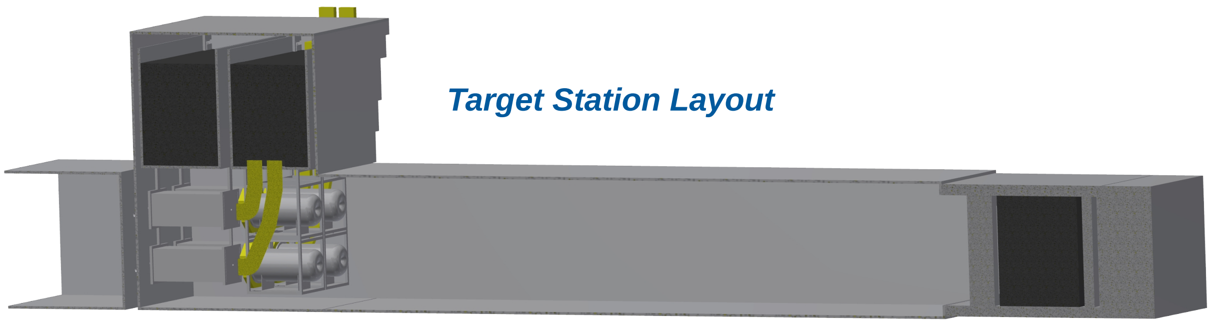
- European Project for production of very intense neutrino super beam for precise measurement of δ_{CP} at the 2nd oscillation maximum, by using the 5 MW proton beam from the ESS linac, under construction in Lund, Sweden (2.5 GeV kinetic energy, 14 Hz repetition rate).
- Proton beam split in 4 beams of 1.25 MW each and directed towards a 4 target/horn system.
- 540 kt fiducial volume of far detector.
  - Two sites in Sweden considered for the FD: Zinkgruvan (360 km), Garpenberg (540 km).
- 60% of δ_{CP} coverage at 5σ C.L. with the current design.



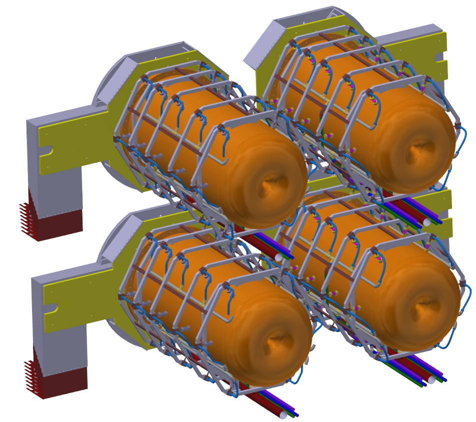
Linac Upgrade ***Accumulator Ring*** ***Target Station*** ***Detector Performance*** ***Physics Reach***

References:
[1] E. Baussan et al., Nucl. Phys. B, 885:127–149 (2014)
[2] M. Dracos et al., PoS, NuFact2019:024, 2020

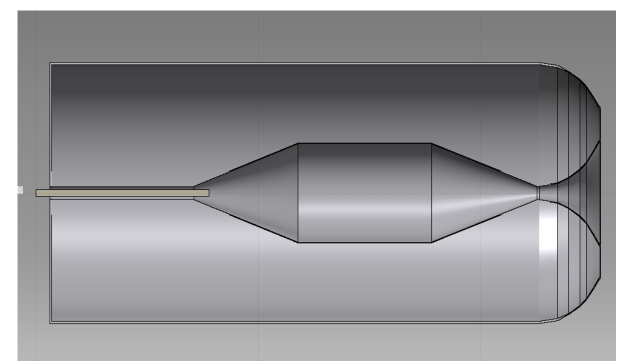
The ESSνSB Target Station



Target Station Layout

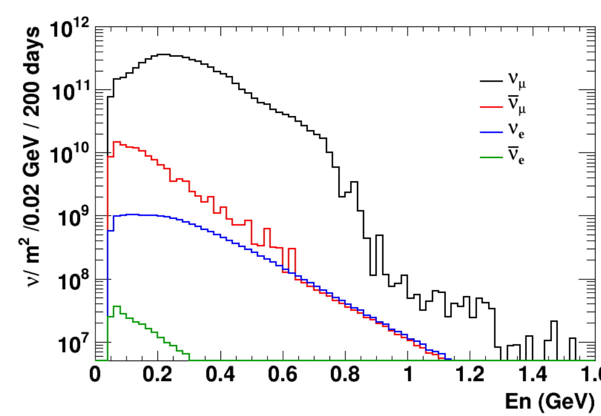


4 Horn System



Target/Horn geometry (N. Vassilopoulos)

- Main components of the Target Station:
  - 4 target/horn system for hadron production/collection
    - Each target consists of a packed bed of titanium spheres. The total radius and length of the proposed target is 1.5 cm and 78 cm, respectively.
    - Each horn has a MiniBooNE-like shape of about 60 cm radius and 2.5 m length each, in the current baseline.
    - The magnetic field is generated by a 350 kA half sinusoidal current pulse in the horn
  - Pions produced and collected are let decay in flight in a decay tunnel (4 m x 4 m x 25 m).
  - The hadrons and muons are then absorbed by a beam dump at the end of the decay tunnel.



Neutrino flux calculated with 2.5 GeV proton beam (neutrino mode)

References:
[1] E. Baussan et al., Phys. Rev. ST Accel. Beams, 17:031001 (2014)
[2] L. D'Alessi, PoS, NuFact2019:062 (2020)

Optimization Procedure

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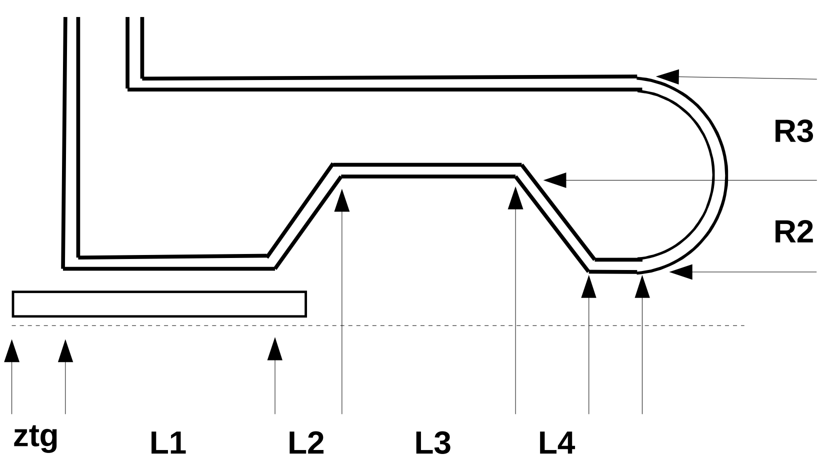
- For this work, we used the Python toolkit DEAP for genetic algorithm based simulations [1]
- The Genetic Algorithm (GA) optimization method has been already used for the design of other neutrino beam experiments, such as LBNO [2] and DUNE [3].
- In this work, different realizations of the 4 target/horn system and decay tunnel are produced and let evolve by using the Genetic Algorithm to find the optimal configuration.
  - The neutrino flux is obtained with a FLUKA [4] code with a simplified geometry of the target station consisting of the 4 target/horn system and the decay tunnel.
  - The neutrino fluxes are used to calculate with GloBES [5] the fraction of range of δ_{CP} values which can be reached at 5σ C.L.. This represents the FoM of our system.
  - At a given generation, after which no significant improvements in the optimization procedure are observed, the configuration with the maximum of fraction of δ_{CP} values covered is considered as the optimal configuration.

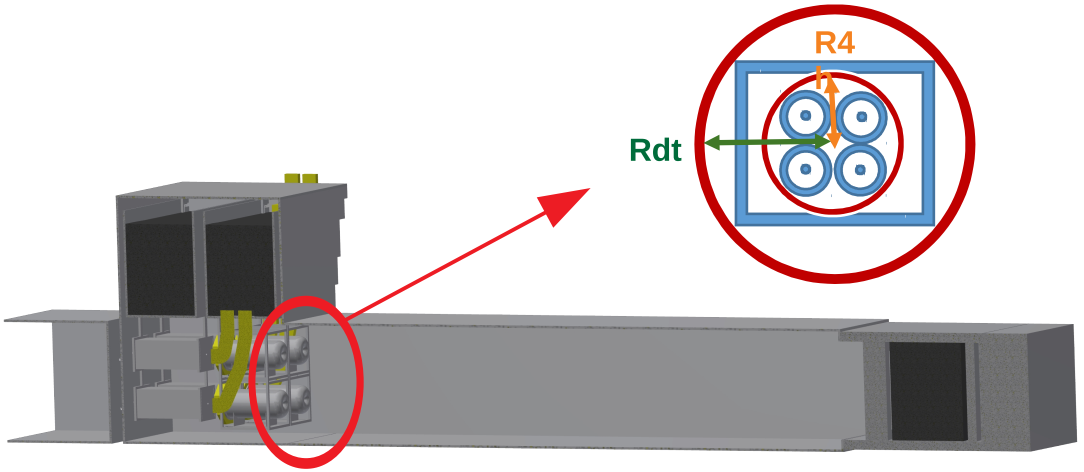
References:

[1] F. Fortin, F.-M. De Rainville, M.-A. Gardner, M. Parizeau, C. Gagné, Journal of Machine Learning Research, 13:2171-2175 (2012)
[2] M. Calviani, S. Di Luise, V. Galymov, and P. Velten, Nucl. Part. Phys. Proc., 273-275:2681–2683 (2016).
[3] R. Acciarri et al., FERMILAB-DESIGN-2016-02, arXiv: 1512.06148 [physics.ins-det] (2016)
[4] A. Ferrari, P. R. Sala, A. Fasso, and J. Ranflt, FLUKA: a multi-particle transport code, CERN-2005-10 (2005), INFN-TC-05-11, SLAC-R-773, V. Vlachoudis, FLAIR: A Powerful But User Friendly Graphical Interface For FLUKA, in Proc. Int. Conf. on Mathematics, Computational Methods & Reactor Physics (M&C 2009), Saratoga Springs, New York, 2009.
[5] P. Huber et al, Comput. Phys.Commun. 167 195 (2005) [arXiv:hep-ph/0407333], P. Huber et al, Comput. Phys. Commun. 177432–438 (2007) [arXiv:hep-ph/0701187]

Optimization Procedure

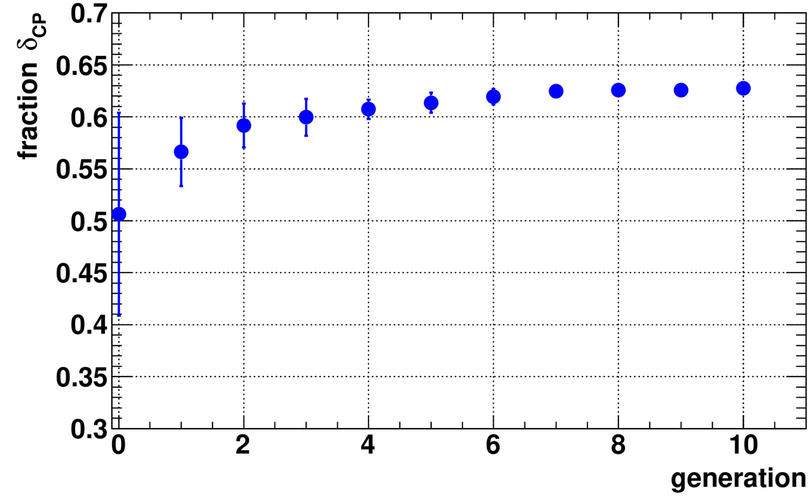
- The starting point of the Genetic Algorithm (GA) applied to the ESSνSB experiment is the current baseline of the Magnetic Horn (MH) and Decay Tunnel (DT) geometry
- For our work, the following parameters of the horn and decay tunnel have been considered:
  - L1, L2, L3, L4, R2, R3, ztg, Ldt (Length of Decay Tunnel)
  - The radius of the Decay tunnel is calculated so that the ratio Rdt/R4h is constant
- The value of the i-th parameter has been rescaled by a scale factor, which value is included in the range [0.5, 1.5], w.r.t. the corresponding baseline value.

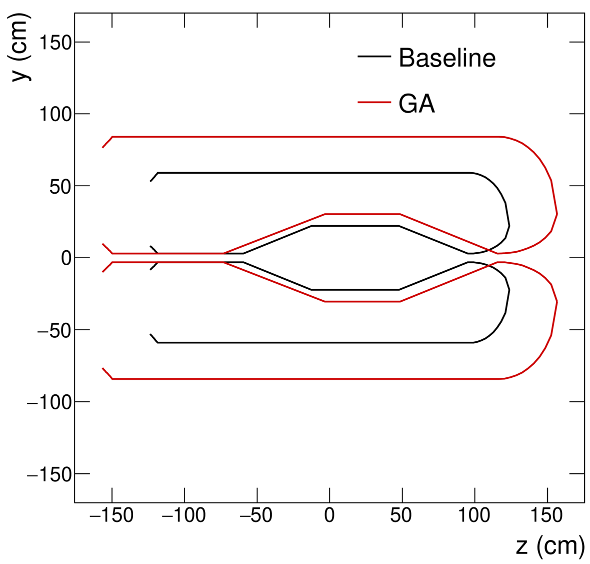


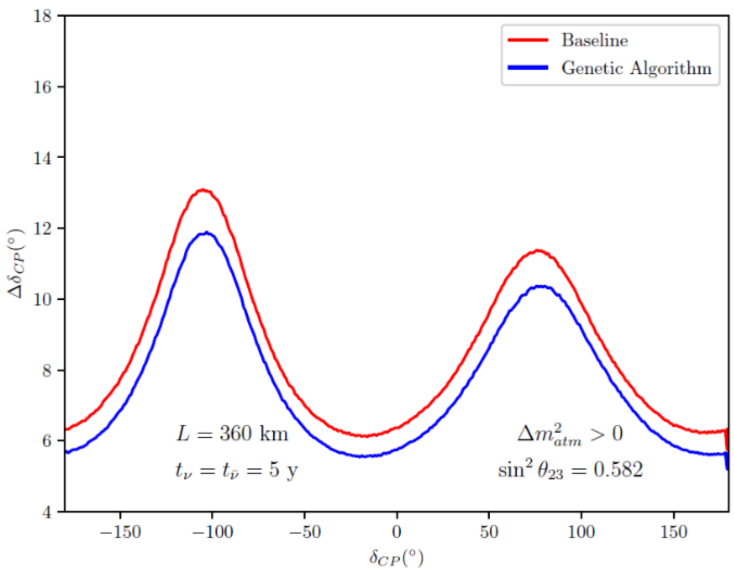


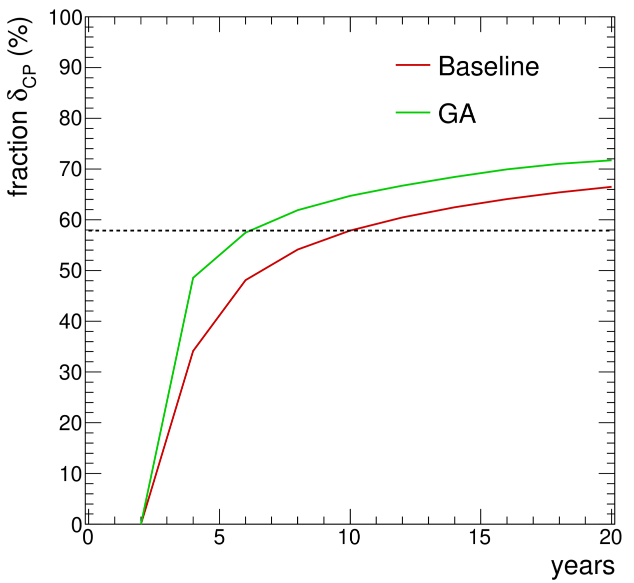
Results

- The convergence of the algorithm is reached already after few generations
- The optimization study seems to go in the direction of larger size of the horn geometry and longer length of the decay tunnel. These results need to be complemented by mechanical studies to determine the feasibility of the new geometry.
- A reduced exposure time is necessary to achieve the same results which can be obtained with the current baseline.









Note: The "baseline" label here refers to the magnetic horn and decay tunnel geometry baseline. Although the current baseline for the FD site is the Garpenberg mine (540 km), in this work we consider Zinkgruvan mine (360 km), which is preferred for the precision on the δ_{CP} measurement.

Conclusions

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- The results of the optimization study by using the Genetic Algorithm shows an improvement in the physics potential of the experiment.

- In particular, the precision in the measurement of δ_{CP} seems to improve and at the same time, the same precision which can be achieved with the baseline can be obtained within a reduced exposure time.

- Studies are currently on going to determine the feasibility of the horn geometry suggested by the optimization study, from the mechanical point of view.

Acknowledgement

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Thank You for Your Attention!