Status of the ESSνSB Target Station Design

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CP-Violation in Leptonic Sector

- CP-violation (CPV) responsible for matter/anti-matter asymmetry.
- It has been seen in the baryonic sector (on a small scale)[1]
- ➔ not enough to explain the observed matter/anti-matter asymmetry.
- It has not been confirmed yet in the leptonic sector
- ➔ T2K has recently reported closed 99.73% (3σ) intervals on the CPV phase, δ_{CP}[2].
- Neutrino mixing relates the neutrino flavor and mass eigenstates through the PMNS unitary matrix.

$$U = \begin{pmatrix} 1 & 0 & 0 \\ 0 & cos\theta_{23} & sin\theta_{23} \\ 0 & -sin\theta_{23} & cos\theta_{23} \end{pmatrix} \begin{pmatrix} cos\theta_{13} & 0 & sin\theta_{13}e^{-i\delta_{CP}} \\ 0 & 1 & 0 \\ -sin\theta_{13}e^{i\delta_{CP}} & 0 & cos\theta_{13} \end{pmatrix} \begin{pmatrix} cos\theta_{12} & sin\theta_{12} & 0 \\ -sin\theta_{12} & cos\theta_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

Fig. 1: The PMNS matrix. The first matrix expresses the oscillation in the "23/atmospheric sector", the second matrix in the "13/reactor sector" and the third matrix in the "12/solar sector". The second matrix is responsible for the leptonic CP-violation.

ESSνSB

European Spallation Source neutrino Super Beam

The ESSνSB Experiment[3]

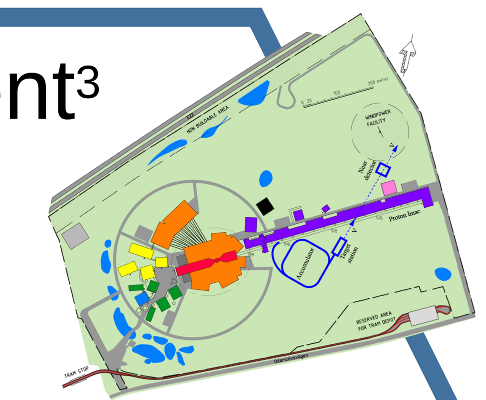


Fig. 2: Layout of the ESS site.

- Aims at searching the CPV in the leptonic sector
  - ➔ at 5σ C.L. level (> 60% of the leptonic Dirac δ_{CP}).
  - ➔ precision measurement of δ_{CP} value.
- Uses intense neutrino beam generated by the ESS[4] 2.5 GeV, 5 MW LINAC proton beam in Lund (Sweden).
- The far neutrino detectors:
  - ➔ Two water Cherenkov detectors with total fiducial mass of over 500 kt.
  - ➔ 540 km-baseline/1.2 km-overburden.
  - ➔ Measures at the 2nd oscillation maximum.
  - ➢ Advantage: ~ 3x higher in CPV sensitivity vs measuring at the 1st oscillation maximum.

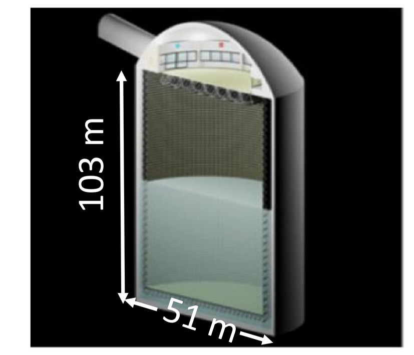


Fig. 3: Memphis-like far detector.

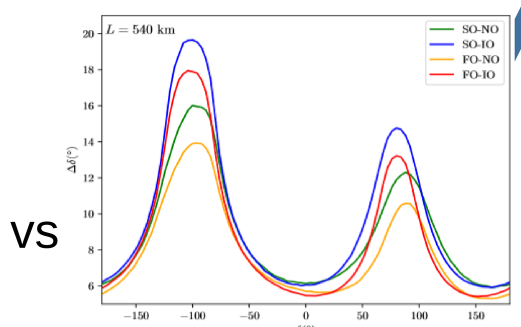


Fig. 4: Precision measurement for δ_{CP}[5].

Target Station Facility

- Responsible to produce the intense neutrino beam.
- Constructed from:
  - ➢ Sets of 4-baffle and collimators, targets and magnetic horns within a single large helium vessel, to mitigate the power on each target.
  - ➢ A 4x4m², 25m long Decay tunnel ➔ $\pi^{\pm}$ mesons decay to neutrino beam.
  - ➢ Beam dump (graphite core).
  - ➢ Utility control sections: power supply unit, Hot cell, morgue, shielding and control room.

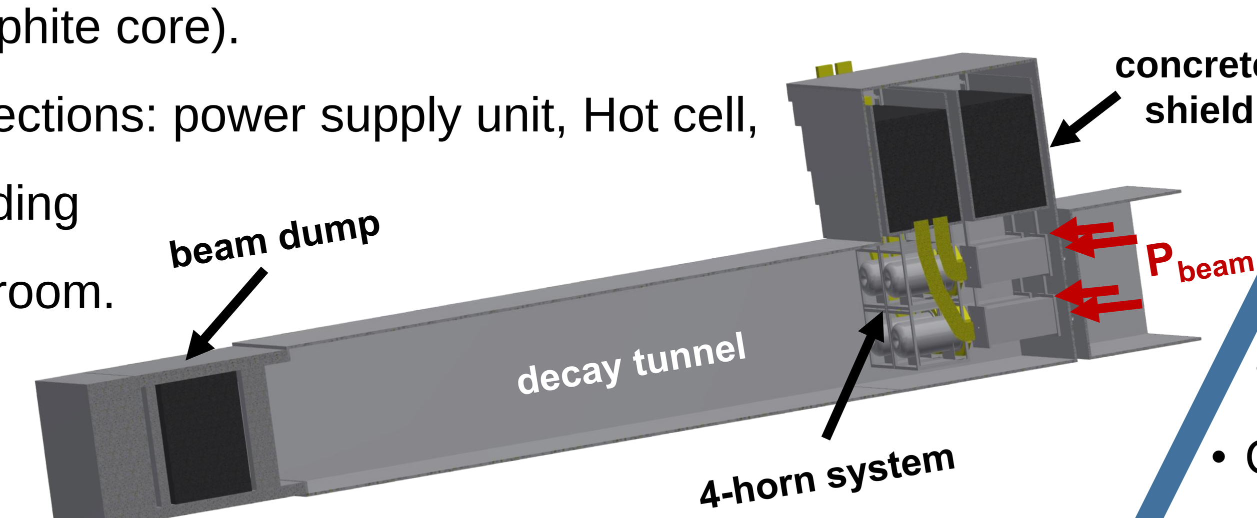


Fig. 5: CAD drawing of the ESSvSB target station, decay tunnel and beam dump.

4-Horn Focusing System

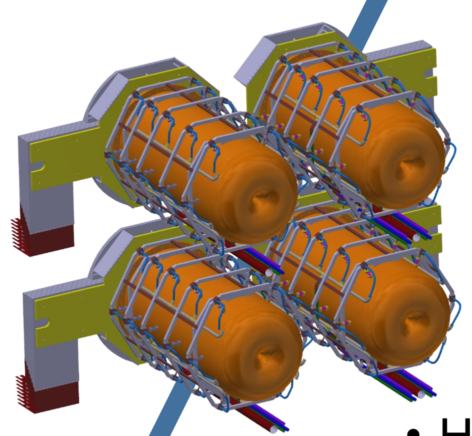


Fig. 6: The 4-horn system.

- Four separated horns, target canister in the horn middle.
- Aluminum conductor with outer (10 mm)/inner (3 mm), thickness and water cooled.
- Horn current 350 kA/14 Hz/100 µs-pulse.

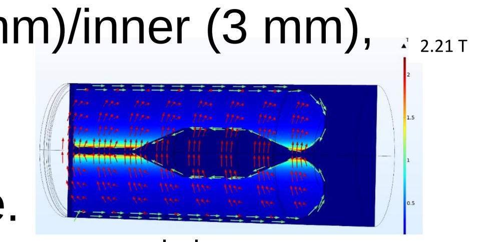


Fig. 7: $\vec{B}$, $|\vec{B}|$ and I direction in the horn.

- Toroidal $\vec{B}$ field inside the cavity, with max. *B*-value of 2.21 T.
- Current polarity depends on the π± focusing operation mode.

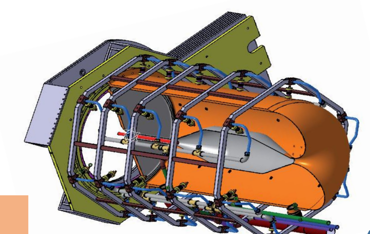


Fig. 7: Interior view of one horn.

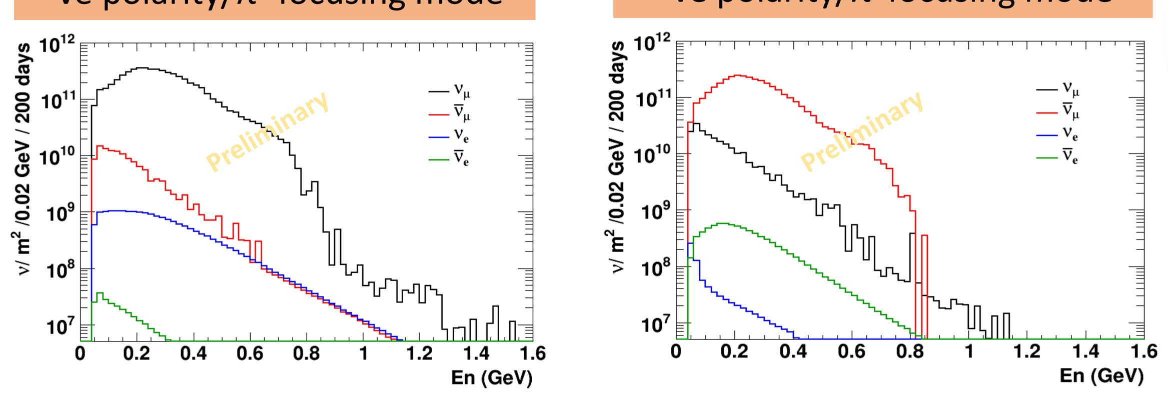


Fig. 8: ν flux distributions as a function of ν energy for different focusing modes.

Beam Dump

- Protects the site behind the decay tunnel from radio-activation.
- Different graphite core designs, with outer layout 4 x 4 x 3.2 m³.

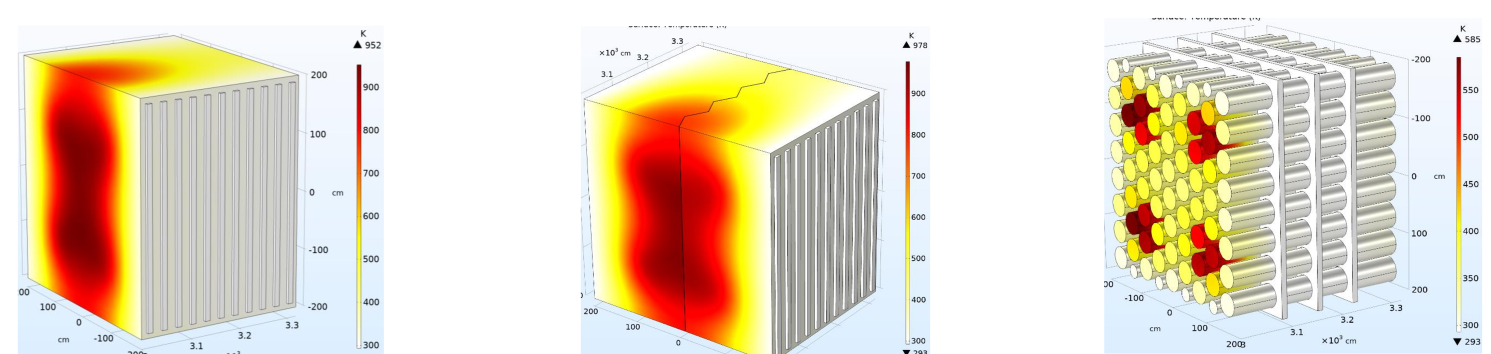


Table 1: Summary of the results obtained from studying the design evaluation parameter.

ESSvSB Beam Dump Core							
Core geometrical design	Material (s)	Cooling technique	Mass of the total/main piece [kg]	Max. Temp. [K]	Max. displacement [mm]	Max. stress (von Mises) [MPa]	Stopping power for all particles [%]
One-block	Graphite/Cu	Dry/bars	~ 100 000 (C) ~ 179 (Cu)	952	5.62	3.65	> 99
EuroNuNet	Graphite/Cu	Dry/bars	~ 100 000 (C) ~ 179 (Cu)	972	6	3.56	> 99
Multi-cones	Graphite/Cu	Dry/frame	~ 897 (C) ~ 4 650 (Cu)	585	0.66	2.77	> 88

Packed-Bed Target

- Four solid packed-bed, 1.5 mm radius Ti spheres, contained in a 15 mm-radius, 780 mm-long canister.
- 1.25 MW @ of 14 Hz ESS proton beam on target.
- Cooled based on longitudinal He flow in the bulk of the canister
  - ➢ Disadvantage: drastic reduction in cooling the spheres at the canister back.
- New multi-entries transverse cooling system is under study
  - ➢ Advantage: homogenous cooling of the spheres in the canister bulk.

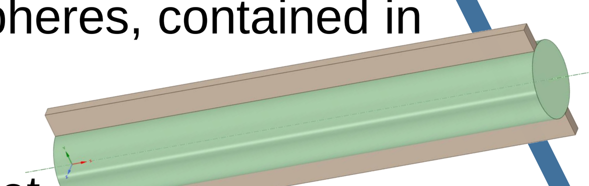
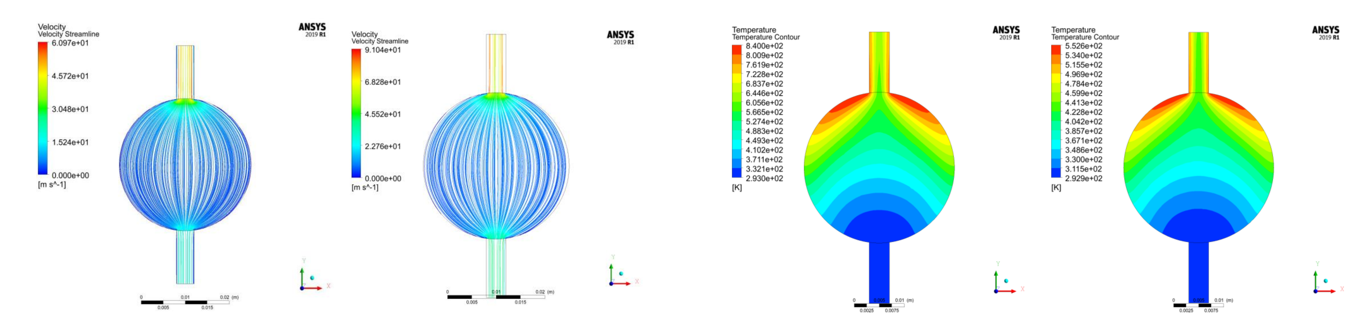


Fig. 9: Target canister with cooling bars.



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