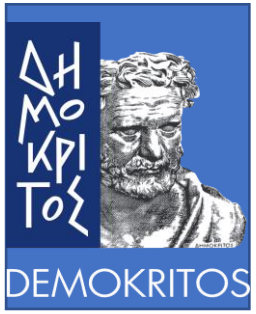


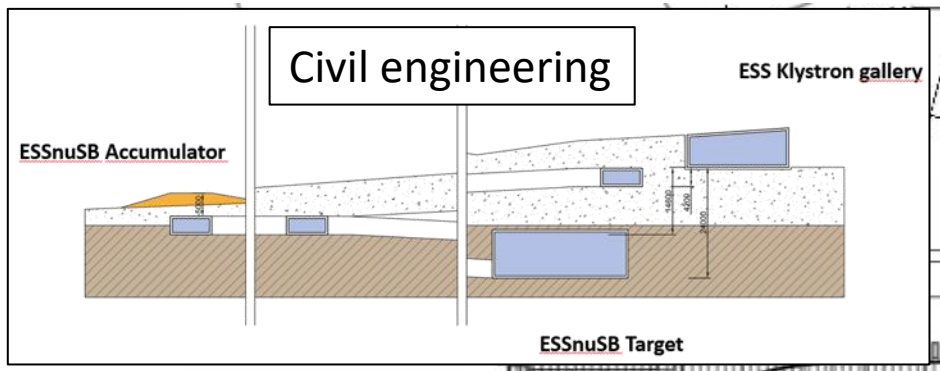
Co-funded by the
European Union

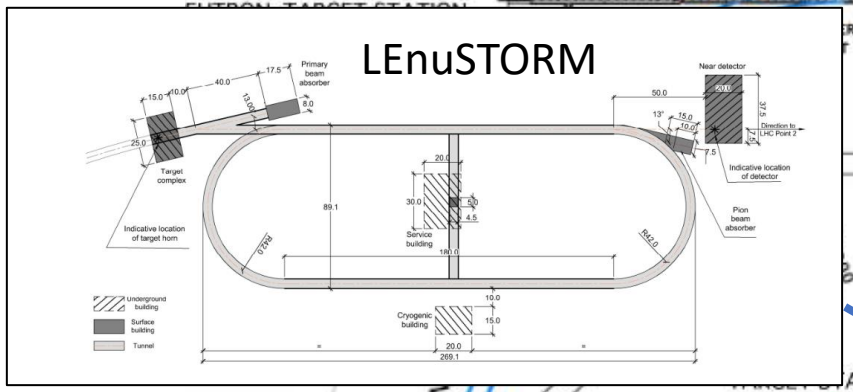
ESS Neutrino Super Beam Plus

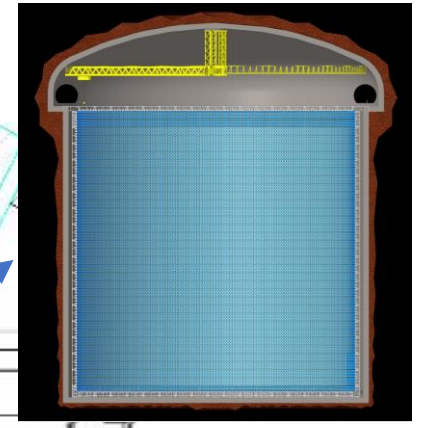
Some initial thoughts towards the design of the Low Energy neutrino Monitored Beam and LEnuSTORM Near Detector – Lemon-D

George Fanourakis, Spyros Tzamarias et al.

ESSnuSB+

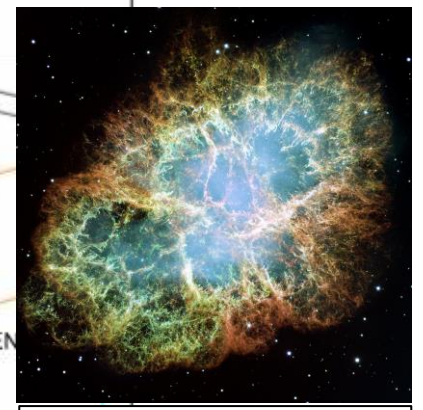






Mining

Gd doping



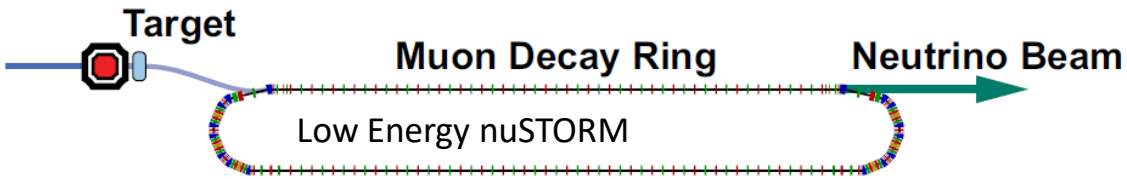
Additional physics

New detector for LEnuSTORM and monitored beam

R&D target station
(1.25 MW out of the 5MW).
Feeding LEnuSTORM and monitored beam.

LEnuSTORM physics potential

The Low Energy neutrinos from STORed Muons facility allows for several Physics studies at ESS



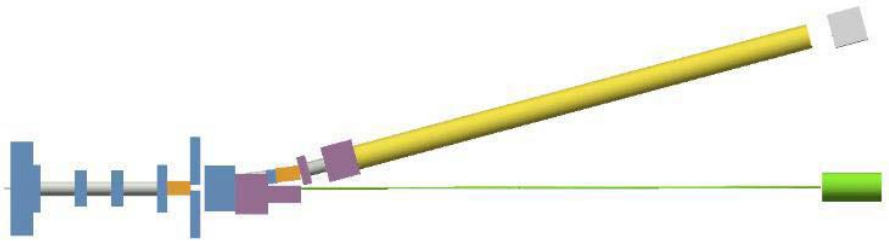
- LEnuSTORM can produce intense, flavor pure neutrino beams (characterized by beam and ring instrumentation) of precisely known flux out of ~450MeV/c muons. $\mu^+ \rightarrow e^+ + \bar{\nu}_\mu + \nu_e$ or $\mu^- \rightarrow e^- + \nu_\mu + \bar{\nu}_e$
  - Neutrino Interaction cross sections can be measured with excellent precision.

- LEnuSTORM can be used to realize a Short Base Line (SBL) neutrino oscillation experiment, using a new magnetized iron Near detector and the ESSnuSB near detector as a Far detector.
  - Use the "golden channel" in which a neutrino oscillation appearance signal is given by the observation of the "wrong sign" muon in the signal event. For example: with μ+ stored in LEnuSTORM (ν_e and anti-ν_μ production) the oscillation $\nu_e \rightarrow \nu_\mu$ will produce a ν_μ CC interaction with a μ^- in the final state, which is the "wrong sign" with that expected by the CC interactions of the anti-ν_μ beam.

- LEnuSTORM can be used to perform searches of sterile neutrinos with unmatched sensitivity: Looking for ν_μ appearance and anti-ν_e disappearance (in the case of μ+ stored muons).

LEMNB physics potential

The Low Energy Monitored Neutrino Beam at ESS



- LEMNB can produce well defined neutrino tagged beams with a technique to be developed.
  - Neutrino Interaction cross sections can be measured with excellent precision.
  - Exploring sterile neutrino scenario as with the LEnuSTORM.

- LEnuSTORM and LEMNB will share the same near detector.

- LEMNB will be the first Instrument to be constructed and operational since it may have no need for an accumulator.

LEMON-D requirements

$$\pi^- \rightarrow \mu^- + \bar{\nu}_\mu$$

$$\pi^+ \rightarrow \mu^+ + \nu_\mu$$

$$\frac{\Gamma\left(\pi^- \rightarrow e^- \bar{\nu}_e\right)}{\Gamma\left(\pi^- \rightarrow \mu^- \bar{\nu}_\mu\right)} = \frac{m_e^2\left(m_\pi^2 - m_e^2\right)^2}{m_\mu^2\left(m_\pi^2 - m_\mu^2\right)^2} \approx 1.3 \times 10^{-4}$$

$$\mu^- \rightarrow e^- + \bar{\nu}_e + \nu_\mu$$

$$\mu^+ \rightarrow e^+ + \nu_e + \bar{\nu}_\mu$$

- Lemon-D will detect neutrino interactions from LEnuSTORM and LENMB and will be located ~50 m away from their production points.
  It will consist a short base line ν osc. experiment with ESSnuSB ND
- water target
  Interleaved with active detector elements
- ν / ν-bar discrimination
  - μ+ and μ- tagging
  - e+ and e- tagging
  - magnet
- Good timing
- Good energy and momentum resolution (how good to be determined)
- Cosmic ray protection/discrimination

LEMON-D parameters

Input: neutrino energy and angle distributions vs distance from the sources

- Distance from neutrino sources
- Dimensions (to be determined based on containment issues, on the required precision for the x-section measurement but also in conjunction with the given dimensions of the Near detectors)
- Target material and interleaved detector elements thickness
- Magnet size and magnetic field required
- What rate should the detector be able to withstand?
- Cosmic rate veto counters (type, size)

Near detectors (at 0.25 Km)

Monitor neutrino beam intensity and measure muon and electron neutrino and antineutrino cross sections