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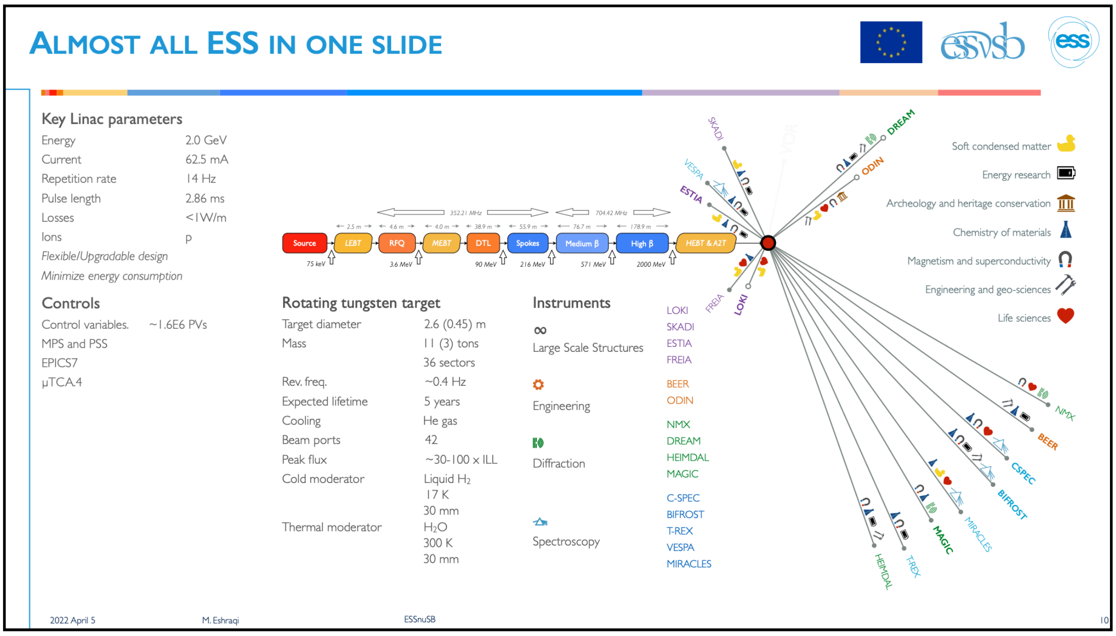
ESSnuSB - a neutrino super beam from the ESS linac by Mohammad Eshraqi (ESS)

The European Spallation Source (ESS) is a multi-disciplinary research facility based on the **world's brightest pulsed neutron source**. It is currently under construction in Lund, Sweden: **the ESS project has seen good progress recently with the RFQ beam commissioning completed**. The 13 European member countries act as partners in the construction and operation of ESS. **ESS will start the scientific user programme in 2025, and the construction phase (which started in 2014) will be complete by 2025**. When completed ESS will be the world's brightest next-generation neutron source driven by the most powerful proton linac, and will enable scientists to see and understand basic atomic structures and forces at length and time scales unachievable at other neutron sources. ESS will use spallation process, a process in which neutrons are liberated from heavy elements upon being impacted by high energy protons, and will be able to deliver a neutron flux two orders of magnitude higher than fission based neutron sources. Unlike existing facilities, the ESS is neither a "short pulse" (micro-seconds) spallation source, nor a continuous source like the SINQ facility in Switzerland, but **the first example of a "long pulse" source (milli-seconds)**. The future facility is composed of a linear accelerator in which protons are accelerated and collide with **a rotating, helium-cooled tungsten target**. By this process, intense pulses of neutrons are generated. Surrounding the tungsten, there are two moderators, i.e. baths of water and liquid hydrogen, which will slow them down to epithermal and ultra-cold neutrons, respectively, and feed supermirror guides. These operate in a similar way to optical fibres, directing the intense beams of neutrons to experimental stations, where research is done on different materials. **A one-slide summary of ESS is shown below**, from which the proton beam power hitting the target can be computed:

$$P_{beam} = \frac{Energy}{e} \times Current \times RepRate \times PulseLength = 5 \text{ MW}.$$



As the linac will work only 4% of the time and there is some empty space on the site, it was proposed to study and design a neutrino super beam from the ESS linac (ESSnuSB: see https://essnusb.eu/) for precision measurements of CP violation in the lepton sector: ESSnuSB is a collaboration of 15 institutes having received funding, during the last four years (2018-2021), from the European Union's Horizon 2020 research and innovation programme under grant agreement No 777419. The goal was to **raise the beam power from 5 MW to 10 MW by increasing the duty cycle from 4% to 8%, adding an H- beam**. The high beam intensity will make **measurement of neutrino oscillations at the second maximum possible**, thereby reducing the sensitivity of the measurements to systematic errors and matter effects as compared to measurements made at the first oscillation maximum. The Conceptual Design Report (CDR) is completed and is being edited, to be published soon. The CDR covers the linac upgrade, the accumulator, the target, both detectors and the physics reach in detail, explaining how the ESS linac can be upgraded from 5 MW to 10 MW to deliver 1E23 p.o.t/year. Neutrino oscillation studies could then be performed using two water Cherenkov (near and far) detectors located at 250 m and 370 km from the target respectively.

Q&A session:

- The specificity of driving the ESS Linac with H-, first designed to operate with a proton source, was further discussed, and its stability towards the requirement to limit losses at 1 W/m was elaborated.

- Neutrino superbeams are designed with a split of the beam onto four target stations equipped with a horn system. A special emphasis was made during the study on the optical properties of the generated muon beams and the merging of the four stations into a single beam, while the targets and related target stations were already investigated in previous programs (euronu, laguna). The reduced footprint of the target station originates from natural shielding provided by 20 m underground positions, as well as a moderate beam energy of 2 GeV, as compared to the beam energy of other accelerator-based facilities.

- A possible follow-up project focusing on muon beam production is under elaboration.

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