Long-term Planning

- NuPECC Long Range Plan 2024 (concluded)
- European Strategy for Particle Physics (update starting)

NuPECC Long Range Plan 2024

- NuPECC = Nuclear Physics European Collaboration Committee http://www.nupecc.org/
- New Long Range Plan: identifying opportunities and priorities for nuclear science in Europe.
- Previous Long Range Plan (2017): http://nupecc.org/pub/lrp17/lrp2017.pdf
  - Neutrino interactions with nuclei not mentioned...

NuPECC Long Range Plan 2024

- NuPECC = Nuclear Physics European Collaboration Committee http://www.nupecc.org/
- New Long Range Plan: identifying opportunities and priorities for nuclear science in Europe.
- Call for community input:
  - **153 contributions were presented**: https://indico.ph.tum.de/event/7050/contributions/
  - Neutrino scattering and nuclear structure
    - Contact: LAR, N. Jachowicz
    - https://indico.ph.tum.de/event/7050/contributions/6335/
  - Electron Scattering and Neutrino Programs
    - Contact: Kendall Mahn, Vishvas Pandey
    - https://indico.ph.tum.de/event/7050/contributions/6372/
  - Uploaded in https://indico.fnal.gov/event/57562/

NuPECC Long Range Plan 2024

- NuPECC = Nuclear Physics European Collaboration Committee http://www.nupecc.org/
- New Long Range Plan: identifying opportunities and priorities for nuclear science in Europe.
  - presented in November 2024
  - https://www.nupecc.org/lrp2024/Documents/nupecc_lrp2024.pdf

NuPECC Long Range Plan 2024

- Hadron Physics chapter:

the nature of neutrinos? The search for BSM physics using precision probes has taken centre stage in subatomic physics and will remain a crucial hunting ground for years to come. In this endeavour, hadron physics plays a central and interconnecting role in the measurement and interpretation of precision observables. Prominent examples of precision probes are the anomalous magnetic moment of the muon, referred to as the *muon g-2*, rare hadron decays, the overall quest to understand the flavour structure of quarks and neutrinos, as well as searches for electric dipole moments (EDMs). In all aforementioned

Recent achievements and highlights

Neutrino interactions and oscillations

The existence of neutrino oscillations has established that lepton flavour symmetry is broken, providing the so far only direct indication of BSM physics. Precise determination of oscillation parameters in reactor and accelerator experiments such as T2K and NOvA, has been undertaken in recent years. This experimental programme critically relies on our understanding of neutrino interactions with nucleons and nuclei, which is improving thanks to recent data from T2K and MINERvA. Extraction of the nucleon axial form factor and parton distribution functions have been pursued, as well as weak meson production. Electron- and meson-nucleon-scattering data are also relevant to developing realistic simulations of neutrino interactions at the detectors.

Future prospects

Neutrino interactions and oscillations

The future HyperKamiokande and DUNE experiments aim to establish CP violation in the lepton sector. This calls for realistic modelling and precise measurements of neutrino scattering cross sections over a broad range of energy scales. The CERN Forward Physics Facility will provide the neutrino beam necessary to probe not only the Deep Inelastic Scattering regime but also the quark-hadron transition region. Complementary measurements are possible at electron scattering facilities e.g. MAMI and JLab, and at hadron scattering experiments such as ProtoDUNE at CERN. The NA61/SHINE experiment at CERN is expected to play a key role in reducing the uncertainties in the neutrino flux in hadron scattering experiments. All these efforts will bring this field into the precision era. Furthermore, accurate determination of nucleon axial form factors with controlled systematics will provide valuable input for the ongoing neutrino physics programmes. As the formalism for resonances develops, the $N \to N^*$ and $N \to \Delta$ axial transition form factors will complement such input.

NuPECC Long Range Plan 2024

Nuclear Structure and Reaction Dynamics chapter:

Impact in nuclear astrophysics

Nuclear physics input (S-factors, beta-decay half-lives and beta-delayed neutron emission probabilities of neutron-rich nuclei, masses, neutron-capture probabilities, fission, neutrino-nucleus interactions, ...) are key quantities to understanding the synthesis of elements in the Universe and stellar dynamics (see Chapter Symmetries and

In long-baseline neutrino experiments (e.g. DUNE, Hyper-K, ORCA, PINGU), broad neutrino beams hit a nuclear detector producing charged particles. Neutrino interactions with nuclei need to be accurately modelled to extract oscillation parameters such as neutrino masses and the neutrino mixing charge-parity (CP)-violating phase that is related to the matter-antimatter asymmetry. Several theoretical frameworks are being explored, ranging from ab-initio methods to density functional theory. Their validity needs to be first tested on precise electron scattering data on nuclei. At low energies, neutrino-nucleus scattering is also relevant for the searches of supernova neutrinos. Additionally, coherent elastic neutrino scattering can be used to learn about physics beyond the standard model and to extract the neutron-skin thickness of a target nucleus as an alternative to pa-

Nuclear Physics Tools – Detectors and Experimental Techniques chapter

gies. As neutrinos travel from their source to the detector they undergo flavour oscillations. A range of neutrino parameters can be extracted by comparing fluxes of neutrinos of a specific flavour at the source and the detector. Current and upcoming oscillation experiments rely on the detection of the Cherenkov light generated by neutrino interactions in water or ice (KM3NeT, ICECube, Hyper-Kamiokande), of the scintillation light emitted by appropriate scintillation detector materials (SNO+, JUNO, T2K, NoVA), or the use of liquid argon time projection chambers (DUNE, ICARUS/MicroBooNE/SBND). Given their huge dimensions and anticipated performance, these experiments can simultaneously measure several neutrino sources and thus offer a broad physics programme, primarily devoted to shedding light on the fundamental neutrino properties. The study of beta decay, on the

Scattering on nuclei

Incomplete knowledge of the cross sections and nuclear form factors for interactions between particles and nuclei is a source of systematic uncertainty in many experiments described here. Neutrino and dark matter experiments both need to know the cross sections of neutrinos interacting with the nuclei in the target materials. Dark matter experiments will eventually need to know nuclear form factors to higher precision.

NuPECC Long Range Plan 2024

Hadron Physics

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Nuclear Structure and Reaction Dynamics

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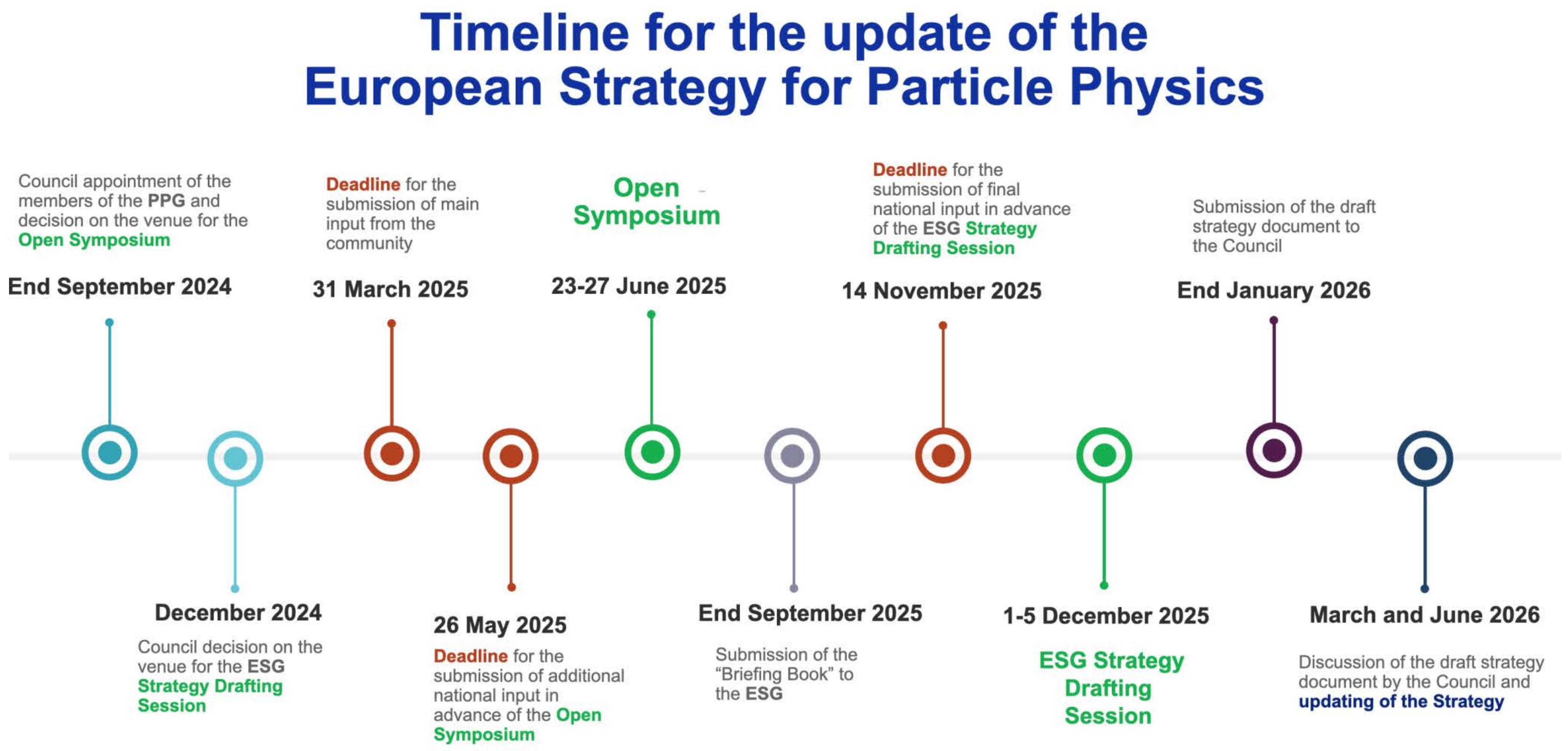
European Strategy for Particle Physics

- https://europeanstrategy.cern/european-strategy-for-particle-physics
- Third update (2024-26)



European Strategy for Particle Physics

- https://europeanstrategy.cern/european-strategy-for-particle-physics
- Third update (2024-26)
- Community input
  - Guidelines: https://indico.cern.ch/event/1439855/page/35202-guidelines
    - **Deadline: March 31, 2025**
    - Cover page (1 page), Comprehensive summary (maximum 10 pages), Back-up document

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- NuSTEC contribution (on behalf of the community)
  - 12 volunteers
  - First meeting: Dec. 16 (15:00 CET = 8:00 CST)
    - Previous European Particle Physics Strategy
    - Topics to cover
    - Other initiatives in preparation (synergies, coordination)
      - Steven Gardiner (generators)
    - Organization of a (one day) meeting
    - How to better advertise our effort