Theory Simulation Tools

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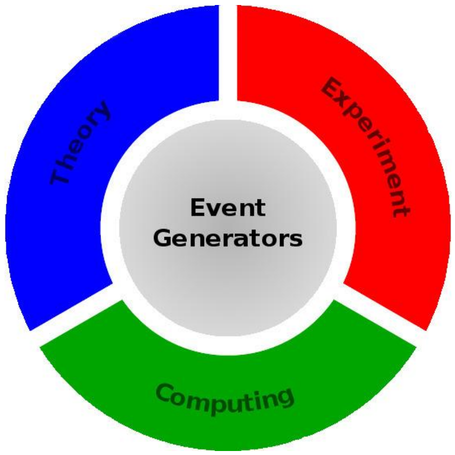
What are Theory Simulation Tools?

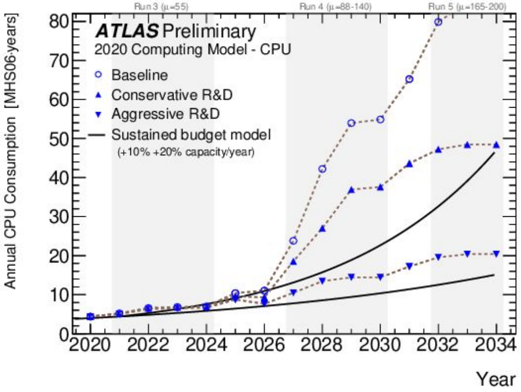
- High-energy physics experiments require complex modeling of our current understanding of the Standard Model
- Proposals for new physics also requires the ability to model the expected observations at experiments
- Proposals for new experiments rely on advanced simulation to help reduce the overall cost
- Simulation tools and related non-perturbative inputs connect all these pieces and include:
    - Parton distribution functions
    - Hadronization modeling
    - Higher order perturbation theory calculations
    - Parton showers and resummation effects

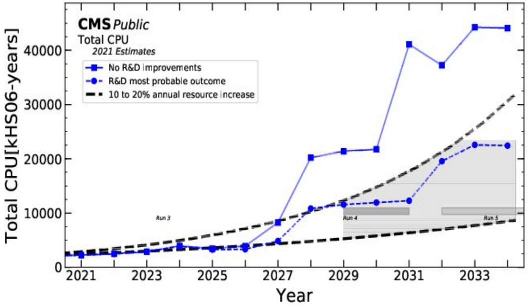
- **These tools preserve the collective knowledge of high-energy particle physicists in a set of calculations and models that are implemented in publicly accessible open-source computer codes (Open Science)**

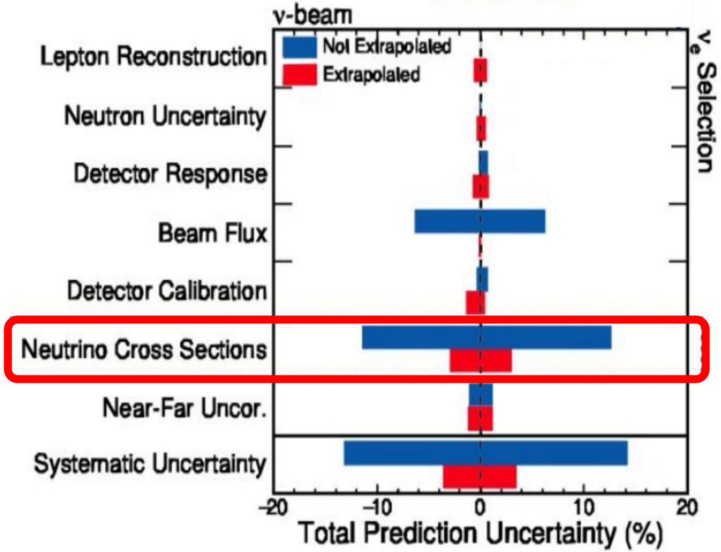


What are the Current Major Obstacles?

- Computational costs at the LHC for higher-order and higher-multiplicity processes put at risk the precision of many measurements.
- The dominant systematic uncertainty in neutrino experiments is the modeling of neutrino-nucleus interactions.







How do we address these obstacles?

Suggestions in the open letter to P5 (http://bit.ly/P5PrecisionOpenLetter2023)

- Introduce a new qualification in “precision analysis”, complementing existing categories like “instrumentation” or “high-performance computing.” Emphasize that such physicists are involved in **cross-disciplinary** research.
- Increase support for the critical components of precision theory simulations. These include focuses on non-perturbative and systematic effects.
- Work to retain junior scientists who have the set of skills to perform these tasks. Many of these programs do not fit well into the typical 3-year postdoc cycle. 5-year (or 3+2-year) fellowships may be more adequate in such cases. Similar positions have been largely successful in the US nuclear physics community.
- On the experimental side, increase the incentives for those working at the intersection of experiment and phenomenology. Understanding the SM at high precision will be the long-term legacy of many experiments.
- While AI/ML will help to solve some of the existing physics issues, appropriately estimating uncertainties and ensuring they are rigorously tested and validated is vital for the understanding and reduction of systematic effects.