

QCD and precision physics

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The LOI is dedicated to

1. The critical importance of precision QFT calculations, including EW and QCD, for the future of particle physics
2. Intention to prepare a Snowmass community document in support of the precision QFT and the necessary infrastructure in the US

The outside role of precision QCD and EW theory in...

Higgs and electroweak precision studies at the (HL-)LHC

searches of direct and indirect signatures of new physics

precision tests of QCD – the exemplary quantum field theory that can be studied in multiple processes in perturbative and nonperturbative regimes

tomography of the 3-dimensional internal structure of nucleons and nuclei at the Electron-Ion Collider at BNL

increasingly likely to happen concurrently with the HL-LHC and advanced lattice QCD computations of hadron structure

Low-energy precision tests of the SM: $g_\mu - 2$, θ_{weak} , dipole moments,...

the high-density phase of QCD: collider forward and diffractive processes, QCD for cosmic ray physics, quark-gluon plasma,...

... ..

Our field is at an interesting historical juncture

“The search for physics beyond the SM will have its best prospects for success when being carried out in parallel with a renewed commitment to SM physics. [...] Data sets being analyzed and those anticipated in the near future could offer the opportunity for a breakthrough precisely in our understanding of QFT. “

“Precision calculation [QCD, EW, even lattice for $(g-2)$] are crucial to the interpretation of future data.”

“[...] the QCD theory community in the US could play a leading role in this, given the existing expertise and the constant outcome of groundbreaking ideas over the past several decades. This is very crucial to the physics of the LHC, and is indeed where another important component, the study of Monte Carlo event generators and how they act as mediators of perturbative and non-perturbative aspects of QCD comes into play.”

A community call to support precision EW/QCD theory in the US

It is vital to have a critical mass of theorists in the US, with strong expertise in both foundational and cutting-edge areas of precision physics

An investment in manpower is needed. One area of weakness is the inadequate funding of postdoc positions in the US, as compared to Europe [and Asia.] “Students interest is high, but it is worrisome to see that most if not all students in precision physics move to Europe for post-graduate research positions.”

Cutting-edge calculations are reliant on **theoretical infrastructure**, particularly in crucial areas like Monte-Carlo event generators, multiloop calculations for collider physics, and determination of PDFs at a corresponding accuracy. **Increased support for theoretical infrastructure is urgently needed** and would create a synergistic effect to realize the potential of advanced experimental measurements and theoretical calculations.



Example

PDF analysis in THE HL-LHC and EIC ERA

Cutting-edge theory	Cutting-edge computing	Cutting-edge statistics
Obtain complete NNLO and N3LO predictions for PDF-sensitive processes	Develop a new generation of high-performance computing codes for PDF analyses	Improve models for correlated systematic errors
Estimate theory uncertainties due to higher-order and higher-twist contributions	Develop and benchmark fast (N)NNLO interfaces	Find ways to constrain large-x PDFs without relying on nuclear targets
Develop PDFs with resummations, NLO EW contributions, for showering programs,...	Implement modern ML/AI methods to determine PDFs and estimate PDF uncertainties in PQCD applications	

(N)NNLO PDFs are used by advanced PQCD computations. They require efforts from multiple groups, shared infrastructure, and base standards in the QCD community. The PDF analysis offers ample opportunities for students and postdocs to work on intersections of theory, experiment, statistics, and computing.

Discussion:

the Snowmass document on QCD and precision physics

1. The format of the document: A community statement? A detailed whitepaper?
 2. Complimentarity with other Snowmass whitepapers or contributions:
 - The N3LO Frontier: Precision Predictions with QCD Perturbation Theory
 - Multi-loop Amplitudes for Colliders
 - Snowmass-Les Houches wishlist
 - Toward PDFs at N3LO accuracy
 - Small-x QCD for cosmic ray physics
 - QCD at the Electron-Ion Collider
 - ...
- } This meeting
- } The EF05/EF06/TF06 meeting, Monday, Nov. 2, 2021