

Snowmass 2021

Energy Frontier - Precision QCD

Kick-off Meeting

Michael Begel (BNL)
Stefan Hoeche (Fermilab)
Michael Schmitt (Northwestern)

May 18, 2020

<https://snowmass21.org/energy/qcd>

Agenda for this meeting

- Introduction to Snowmass process
 - Organizational details
 - Role of our topical subgroup in the Energy Frontier
- Rough outline of physics topics
 - Results of the survey of interests
 - Connection to other topical groups
- Questions and Discussion
 - Raise your hand or speak up if you have questions / comments
 - Add questions to the Live Notes at <https://tinyurl.com/ybl62ww0>

The Snowmass process <https://snowmass21.org/start>

- The Snowmass Process is organized by the Division of Particles and Fields (DPF) of the American Physical Society. Snowmass is an opportunity for the entire HEP community to come together to identify and document a vision for the future of particle physics in the U.S. and its international partners. We aim for everyone's voice to be heard. Your contributions and participation are critical for the success of Snowmass and they will naturally occur as part of one or more working groups directed by the conveners.
- This is a global effort. **Input from non-U.S. based scientists is essential** for the success of Snowmass, and you are encouraged to contribute.

The Snowmass process <https://snowmass21.org/start>

- “Its narrative will communicate the opportunities for discovery in particle physics to the broader scientific community and to the [US] government” (Young-Kee Kim, Town Hall Meeting)
- The Snowmass process is defined as a **science study group**
- **The output of this process will be used as input to the P5** (Particle Physics Project Prioritization Panel) that formulates a 10-year plan (20-year vision) for the U.S. within funding constraints

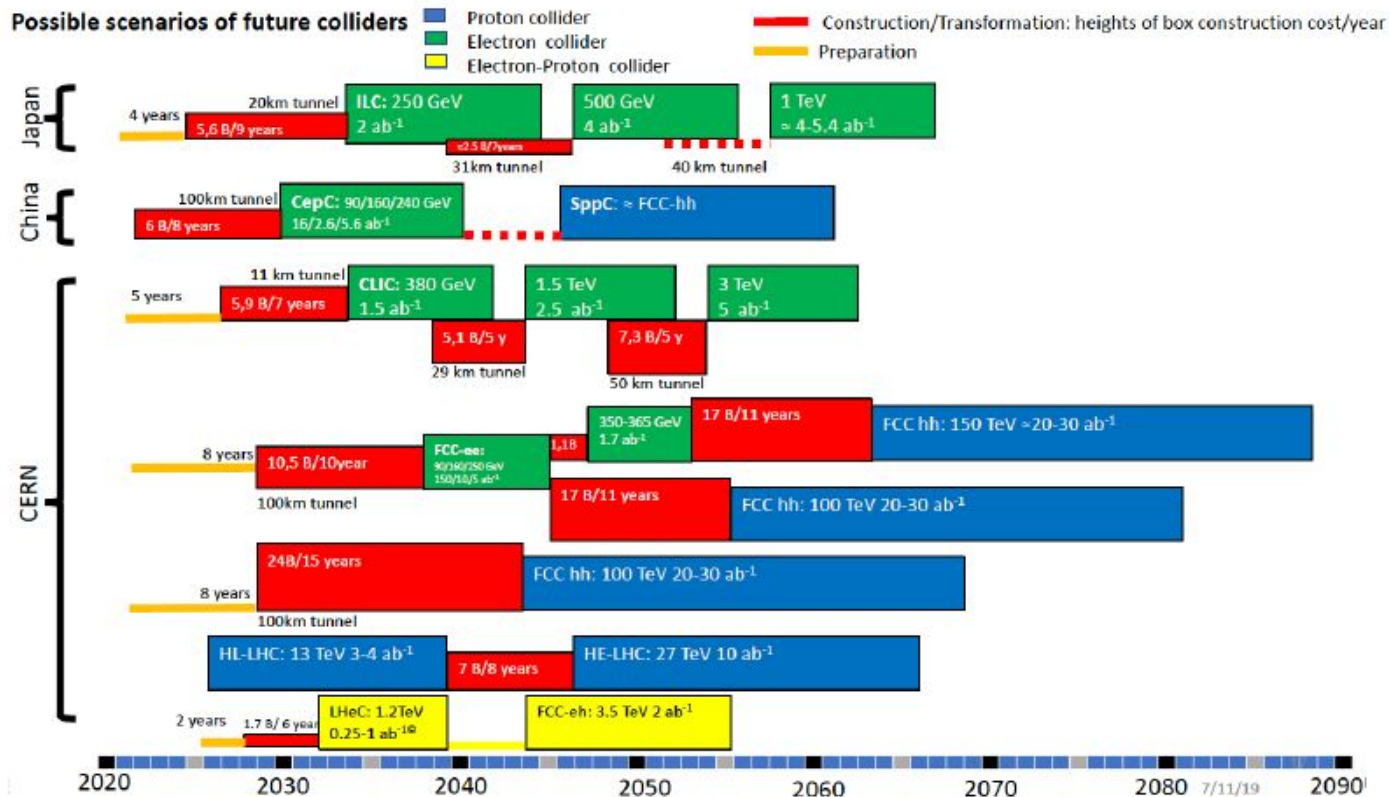
Past Snowmass and P5 reports

- The last Snowmass study took place in 2013
<https://www.slac.stanford.edu/econf/C1307292/>
- The most recent P5 report identified five science drivers
<https://www.usparticlephysics.org/>
 - Use the Higgs boson as a new tool for discovery
 - Pursue the physics associated with neutrino mass
 - Identify the new physics of dark matter
 - Understand cosmic acceleration: dark energy and inflation
 - Explore the unknown: new particles, interactions, and physical principles

Connection to European Strategy Update

- The Physics Preparatory Group has performed comprehensive studies of various future collider options and invested much time to put these analyses on the same footing
- These studies are detailed in the physics briefing book <https://arxiv.org/abs/1910.11775>
- Updates of existing projections should be avoided unless there are significant improvements in physics reach

Connection to European Strategy Update



Ursula Bassler @ Granada meeting

Connection to European Strategy Update

- ESU is a continuous process, and we will stay abreast of developments
 - We will build on these studies and investigate additional scenarios
e.g. muon collider, Electron-Ion Collider, wake-field accelerators, table top devices, etc
- Goal of Snowmass effort is to explore the possibilities for the US
 - new physics opportunities
 - new accelerator and detector technologies
 - new experimental and theoretical techniques
- Outcome of Snowmass is an input into the P5 process
 - similar to how Physics Briefing Book is an input to the ESG
- HEP is a world-wide community — international contributions essential!

Organization of Snowmass 2021

- Kick-off Town Hall meeting on **April 18th** <https://indico.fnal.gov/event/23601/>
- First community meeting: **Nov 4-6, 2020** (Fermilab)
- Final meeting: **July 11-20, 2021** (UW-Seattle) <https://indico.fnal.gov/event/22303/>
 - Studies must have concluded before this meeting, and the WG reports finalized
- Work is categorized in ten frontiers
 - **Energy Frontier**
 - Neutrino Physics Frontier
 - Rare Processes and Precision
 - Cosmic Frontier
 - Theory Frontier
 - Accelerator Frontier
 - Instrumentation Frontier
 - Computational Frontier
 - Underground Facilities
 - Community Engagement Frontier

Organization of Snowmass 2021

The Energy Frontier (EF) group will explore the TeV energy scale and beyond. Agenda includes understanding the heaviest particles of the Standard Model (SM), as well as exploring physics beyond the SM to discover new particles and interactions, including unraveling the mystery of dark matter. In this context, the EF group will carry out (and compile) detailed studies of Electroweak (EW) physics, QCD and strong interactions, and Beyond-Standard-Model (BSM) physics under different future accelerator scenarios, including lepton-lepton, hadron-hadron, and lepton-hadron colliders.

<https://snowmass21.org/energy/start>

Conveners of the EF group: Meenakshi Narain, Laura Reina, Alessandro Tricoli

Organization of Snowmass 2021

- Energy Frontier is split into 10 subgroups, with 3 major categories
 - EW Physics (including EW gauge bosons, Higgs, top)
 - EF01: Higgs Boson properties and couplings
 - EF02: Higgs Boson as a portal to new physics
 - EF03: Heavy flavor and top quark physics
 - EF04: EW precision physics and constraining new physics
 - QCD and strong interactions
 - **EF05: Precision QCD**
 - EF06: Hadronic structure and forward QCD
 - EF07: Heavy Ions
 - BSM Physics
 - EF08: Model-specific explorations
 - EF09: More general explorations
 - EF10: Dark Matter (at colliders)

Communication channels

DPF webpage for Snowmass 2021 Planning

<https://www.aps.org/units/dpf/snowmass-2021.cfm>

Snowmass Wiki: <https://snowmass21.org>

Instructions to join the general mailing list and Slack are at the end of that wiki.

Calendar: <https://snowmass21.org/meetings/start>

Energy Frontier Wiki: <https://snowmass21.org/energy/start>

Instructions to join the topical group mailing lists and Slack are found there

Mailing List: SNOWMASS-EF-05-PRECISION_QCD@FNAL.GOV

Meetings and Workshops

All meetings will be entered on the wiki calendar and can be found on Indico

<https://snowmass21.org/meetings/start>

<https://indico.fnal.gov/category/1098/>

Energy Frontier workshops

- Kick-off Meeting: Thursday May 21, 2020 (full day)
- EF Workshop: July 9-10, 2020 (two full days)

Meeting of the EF05 Topical Group (enter Snowmass21 when prompted)

- Bi-weekly on Monday, 4pm CEST, 10am EDT, 9am CDT, 7am PDT
- Starting today, May 18, 2020

Letters of Interest (April 1 - August 31, 2020)

<https://snowmass21.org/loi>

The purpose of letters of interest (LoI) is to allow Snowmass conveners to see what proposals are coming and to encourage the community to begin studying them. LoIs should give brief descriptions of the proposal and cite the relevant papers to study. These letters will help conveners to prepare the Snowmass Planning Meeting that will take place on November 4-6, 2020 at Fermilab.

- 2 pages not including bibliography
- Uploaded by authors to <https://www.snowmass21.org/upload.php>
- Will be stored permanently in the Fermilab archive
- Authors are encouraged to make a full write up for their work and submit it to the Snowmass proceedings

Contributed Papers (April 1, 2020 – July 31, 2021)

<https://snowmass21.org/submissions>

Contributed papers may include white papers on specific scientific areas, technical articles presenting new results on relevant physics topics, and reasoned expressions of physics priorities, including those related to community involvement. Submitted papers will remain part of the permanent record of Snowmass 2021.

- More extensive studies
- Can but do not have to be related to an LoI
- Submitted by authors following instructions on Snowmass 2021 Wiki (submit to arXiv, email proceedings editors)
- Can be relevant, *recent* studies not performed in the context of Snowmass

EF05 proposed topics

- Strong coupling
 - Measurements and Lattice QCD calculations
 - Level of precision and test of running
- Parton Distributions [with EF06]
 - Measurements needed to improve PDF fits
 - PDF fits needed for higher-order calculations
- Overlap between hadronic physics programs at HL-LHC and EIC
 - Precision calculations for polarized scattering
 - MC simulation for EIC and knowledge transfer from/to LHC [with EF07]
 - Polarized PDFs [with EF06]
- Jet substructure
 - Theoretical calculations and MC modeling
 - Experimental techniques
 - W/Z/H/top tagging

EF05 proposed topics

- Theoretical calculations - Fixed order pQCD
 - NLO & NNLO calculations
 - Survey of results needed for precision physics (NNLO wishlist)
 - Automation of NNLO calculations & embedding in experiments?
 - More advanced calculations needed to reduce theoretical uncertainties
 - Interplay of QCD and EW corrections
- Theoretical calculations - Resummation
 - Event shape variables in e^+e^-
 - Hadronic event shapes
 - Non-global logarithms (VBF etc.)
 - Usage of Effective Field Theories
- Non-perturbative aspects
 - Connections between central and forward QCD [with EF06]
 - Non-perturbative corrections to experimental observables
 - Connections to QIS

EF05 proposed topics

- Physics Observables
 - Higgs production (including non-SM Higgs)
 - Heavy flavor production and threshold corrections
 - Drell-Yan, for the extraction of $\sin^2\theta_W$
 - Di-boson and tri-boson production
 - V+jets, top+jets, Higgs+jets
 - The “ridge” [with EF07]
- MC Event Generators
 - Precision simulation of resolved processes (photons, heavy flavor, ...)
 - Double-parton scattering / multiple parton interactions [with EF06]
 - Hadronization / formation of jets
 - Color reconnection (important at e+e-)
 - Parton showers and connection to resummation
 - Monte Carlo tuning

Responses to Survey

- Distribution of interests (160 replies, rank ordered)
 - Physics Observables (Higgs, heavy quarks, Drell-Yan, multi-boson, jets, ...) 56%
 - Perturbative calculations for total and differential cross sections 49.3%
 - Measurements and calculations needed to improve PDF fits 49.3%
 - Jet substructure (Theory & MC modeling, Experimental techniques, Tagging) 48%
 - Monte Carlo event generators (incl. tuning) 46.7%
 - Connections between central and forward QCD 44.7%
 - Interplay of QCD and EW effects 42%
 - Strong coupling determination 42%
 - Simulations for EIC and knowledge transfer from/to LHC 40%
 - Precision resummation 33.3%
 - Non-factorizable corrections, double-parton scattering, color reconnections 30%
 - Non-perturbative QCD & connections to QIS 30%
 - Strong coupling and PDFs from Lattice 18%

Responses to Survey

- Additional topics of interest
 - **Connections to AI / Machine Learning**
 - Jets at the EIC (including nuclear modification effects in eA collisions)
 - Hadron structure from lattice QCD
 - Precision small-x calculations, interplay between central & forward
 - Applicability region of Regge asymptotics

Connection to other Frontiers and Topical Groups

EF05 overlaps with many other topical groups

- EF01: EW Physics: Higgs Boson properties and couplings
- EF03: EW Physics: Heavy flavor and top quark physics
- EF04: EW Precision Physics and constraining new physics
- EF06: QCD and strong interactions: Hadronic structure and forward QCD
- EF07: QCD and strong interactions: Heavy Ions
- EF10: BSM: Dark Matter at colliders

- TF02: Effective field theory techniques
- TF04: Scattering amplitudes
- TF05: Lattice gauge theory
- TF06: Theory techniques for precision physics
- TF07: Collider phenomenology

Connection to other Frontiers and Topical Groups

EF05 overlaps with many other topical groups

- CompF1: Experimental Algorithm Parallelization
- CompF2: Theoretical Calculations and Simulation
- CompF3: Machine Learning

- AF3: Accelerators for EW/Higgs
- AF4: Multi-TeV Colliders

- IF3: Solid State Detectors and Tracking
- IF4: Trigger and DAQ
- IF6: Calorimetry
- IF7: Electronics/ASICs
- IF8: Noble Elements
- IF9: Cross Cutting and Systems Integration

Connection to other Frontiers and Topical Groups

No sub-groups will be formed within the topical groups.

Working collaborations / liaisons to other topical groups are encouraged.

The role of the liaison / link person is to facilitate communication between Frontiers / topical groups. A liaison will help to establish a working relationship to cooperate on a matter of mutual concerns and interests as a go-between between the groups.

As joint meetings between groups take place in the future, areas that need liaisons / link persons may change.

Monte-Carlo production

- For Snowmass 2013 EF New Particles group, a large SM MC sample was produced [1] for pp collider studies:
 - A technical group within EF was set up.
 - A common detector simulation was used to generate samples at 14, 33 ,and 100 TeV pp colliders using Delphes.
 - common detector = average of ATLAS+CMS
 - Tools for MC generation developed by members of CMS/LPC in collaboration with theory colleagues from SLAC [2].
 - A central production using OSG [3] was set up to generate and validate the samples [4, 5].
- ILC, CLIC, TLEP, gamma-gamma collider, and Muon Collider studies used their own samples and frameworks

[1] <https://arxiv.org/abs/1309.1057> [2] <https://arxiv.org/abs/1308.1636>;

[3] <https://sciencenode.org/feature/power-sharing-osg.php> [4]<https://arxiv.org/abs/1308.0843>

[5] <https://lpc.fnal.gov/lpcsnomass/index.shtml>

Monte-Carlo production

- The landscape of simulations for future colliders has changed since 2013
 - Both future e+e- circular colliders (FCC-ee, CepC) and pp colliders (FCC-hh, CppC) have developed simulation and analysis frameworks, and generated MC samples for their studies.
- Two step strategy to address MC production at Snowmass 2021
 - Assess the EF needs and formulate a plan. A “Task Force” has been formed for this purpose.
 - Produce *needed* MC samples to carry out the necessary studies for EF
- In assessing the needs, the MC Task Force will
 - Consider the processes, the MC generators, the accelerator configurations (c.o.m, integrated luminosity, pileup scenarios, if any), detector configurations, number of events
 - Survey existing frameworks for MC generation and analysis for future colliders (FCC-ee, FCC-hh, CepC, CppC, LHeC, etc.). Are they sufficient, are we permitted to use them?
 - Check/confirm that ILC, CLIC, Muon collider studies will use their frameworks

Monte-Carlo production

- Members of the EF MC task force: John Stupak (Chair),
 - EF conveners: Isobel Ojalvo, Michael Schmitt, Simone Pagan Griso
 - MC authors: Fabio Maltoni, Stefan Hoeche
 - OSG representative: Robert Gardner
- The MC production plan and recommendations will be presented to the EF community and discussed during the July 9-10, 2020 EF Workshop
- The OSG has kindly agreed to support the MC generation for EF, and will provide both compute resources and storage on the OSG Data Federation
- Input to the MC Task Force will be facilitated by the topical group conveners
We will gather your MC requests, provide guidance on the expected theory systematics and try to ensure that requested samples will eventually be used

Plan for the next EF05 meetings

Joint meeting with EF06 & EF07 on

- Lessons from Snowmass 2013
- Updates from European Strategy effort
- Updates from EIC community

Following up on this

- Identification of major topics for the study
- Discussion of technical details (e.g. MC production)
- Exploration of connections to other topical groups

Timeline

- EF Kick-off Meeting: **Thursday May 21, 2020** <https://indico.fnal.gov/event/24264/>
- Letters of Interest (Lol) accepted now through **August 31, 2020**
- EF Workshop: **July 9-10, 2020** (two full days)
 - First opportunity for the community to present ideas, plans and results if already available
- First community meeting: **Nov 4-6, 2020** (Fermilab)
- First draft of Topical Group summaries due **March 2021**
- Final version of written documents due **July 2021**
- Final meeting: **July 11-20, 2021** (UW-Seattle)
- Updated documents (including Lols) due in **November 2021**

Conclusion

Thank you for joining the Snowmass 2021 effort. This is an exciting time in HEP!

We look forward to your ideas and contributions. We are especially glad to work with such a vibrant and enthusiastic group.

Please join with us at our bi-weekly meetings (Mondays @ 10 AM EDT), on our mailing list (SNOWMASS-EF-05-PRECISION_QCD@FNAL.GOV) and our SLACK channel (ef05-precision_qcd).

We will see you at the Energy Frontier Kickoff on Thursday
<https://indico.fnal.gov/event/24264/>