

Theory Frontier Overview

SEC 2021 Frontier Introductions Series

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On behalf of Seth Koren, Soubhik Kumar, Robert McGehee
and the rest of the SEC-TH members

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The Theory Frontier

from TF Kickoff Meeting, July 30

Goal of the theory frontier:

“... articulate the recent advances and future opportunities in all aspects of theory relevant to HEP, including particle theory, formal / foundational theory, cosmological and astro-particle theory, and quantum information science.”

Kicked off on July 30: <https://indico.fnal.gov/event/44512/>

Conveners:



Nathaniel Craig
UCSB



Csaba Csaki
Cornell



Aida El-Khadra
UIUC

Topical Groups

Connections to Experiment,
Other Frontiers

TF01: String Theory, Quantum Gravity, Black Holes

TF02: Effective Field Theory Techniques

TF03: CFT and Formal QFT

TF04: Scattering Amplitudes

TF05: Lattice Gauge Theory

TF06: Theory Techniques for Precision Physics

TF07: Collider Phenomenology

TF08: BSM Model Building

TF09: Astro-particle Physics & Cosmology

TF10: Quantum Information Science

TF11: Theory of Neutrino Physics

Formal Developments

TF01: String Theory, Quantum Gravity, Black Holes

slack: #tf01-strings_gravity

Diverse set of developments that have arisen from studying string theory, AdS/CFT correspondence, and connections to other fields:

- Quantum Aspects of Black Holes
- Many Body Quantum Systems
- String Phenomenology:
Compactification and Unification
- String theory and the early Universe
- New ideas in classical gravity
- New discoveries in mathematics

TF02: Effective Field Theory Techniques

slack: #tf02-eft

Cover developments in effective field theory research applied to a broad range of fields:

- SCET
- SMEFT
- Naturalness
- Swampland/WGC
- EFTs from amplitudes
- Condensed Matter
- Anomaly Matching Techniques
- EFT for Inflation
- NRGR
- EFT of Dark Matter
- + more!

TF03: CFT and formal QFT

slack: #tf03-cft_qft

- CFT, the conformal bootstrap, and related ideas
- SUSY in various dimensions, exact results, localization, integrability, etc.
- IR phases, topological QFTs, aspects of entanglement,
- Non-perturbative methods
- Interfaces between QFT and quantum information
- Interfaces between QFT and pure mathematics

TF04: Scattering Amplitudes

slack: #tf04-amplitudes

Understand amplitudes as relevant for collider physics, connections to fundamental mathematical structures, and other applications, e.g., gravity + LIGO physics

- Geometric pictures, Analytic and Mathematical Properties
- Efficient techniques for constructing amplitudes, recursion relations
- New applications and formal theory connections

TF05: Lattice Gauge Theory

slack: #tf05-lattice

Summarize ongoing and future efforts in lattice gauge theory:

- Quark and Lepton Flavor Physics
- Nucleon and Nucleus response to external probes (neutrino experiments, direct detection)
- SM contributions to symmetry violating processes
- Hadron and Nuclear Structure
- Hot and Dense states of matter
- Strongly Coupled Theories
- New algorithms and frameworks

TF06: Theory Techniques for Precision Physics

slack: #tf06-precision

Survey theoretical techniques developed to meet precision demands of current and future experiments, and discuss novel developments that could lead to new levels of theoretical understanding

- EFTs of QCD
- Multi-Loop Techniques
- NNLO and beyond
- Flavor Physics
- Improvements in MC event generators
- SMEFT
- Non-perturbative effects in HE collisions
- + ...

TF07: Collider Phenomenology

slack: #tf07-collider

Lots of synergy with the Energy Frontier but emphasis on new concepts, techniques, tools, and advances:

- Novel signatures
- Advances in event simulation
- Refined observables
- Broaden range of new physics searches, ...

And connections between collider pheno and other theory frontier activities

TF08: BSM Model Building

slack: #tf08-model_building

Advertise exciting directions in BSM, impact on other areas of HEP, long-term questions and recent developments

Cross-cutting with lots of the other TF groups and other frontiers

Answers to Questions Like:

- Dark Matter
- Fermion Masses
- Dark Energy
- Baryon Asymmetry
- Naturalness, Unification, String Pheno
- Portals to New Sectors
- Experimental Anomalies
- ...

TF09: Astro-particle physics and Cosmology

slack: #tf09-astro_cosmo

Potential Ideas:

- Inflation, Dark Energy and Connections to Formal Theory
- Data-Driven Cosmology (CMB, LSS, BBN, 21cm)
- Early Universe Model Building
- Indirect Detection (Cosmology + Astrophysics)
- Connections to dark sector physics

TF10: Quantum Information Science

slack: #tf10-qis

Aspects of QIS relevant to HEP:

- Algorithms for quantum simulating QFTs
- Novel approaches to fundamental physics with quantum systems & sensors
- Connections between entanglement, quantum information and holography
- Computation and theoretical components of QIS
- + ...

TF11: Theory of Neutrino Physics

slack: #tf11-neutrinos

- Neutrino Phenomenology
- Neutrinos in Astrophysics and Cosmology
- Nucleons and Nuclei for Neutrinos: Neutrino scattering and Neutrino less double-beta decay

Cross-talk between the Neutrino Frontier and the Theory Community

Topical Group Conveners

TF01:	String Theory, Quantum Gravity, Black Holes	Daniel Harlow (MIT), Shamit Kachru (Stanford), Juan Maldacena (IAS)
TF02:	Effective Field Theory Techniques	Patrick Draper (UIUC), Ira Rothstein (CMU)
TF03:	CFT and Formal QFT	David Poland (Yale), Leonardo Rastelli (Stony Brook)
TF04:	Scattering Amplitudes	Zvi Bern (UCLA), Jaroslav Trnka (UCD)
TF05:	Lattice Gauge Theory	Zoreh Davoudi (UMD), Taku Izubuchi (BNL), Ethan Neil (CU Boulder)
TF06:	Theory Techniques for Precision Physics	Radja Boughezal (ANL), Zoltan Ligeti (LBNL)
TF07:	Collider Phenomenology	Fabio Maltoni (Louvain/Bologna), Shufang Su (Arizona), Jesse Thaler (MIT)
TF08:	BSM Model Building	Patrick Fox (FNAL), Hitoshi Murayama (UC Berkeley)
TF09:	Astro-particle Physics and Cosmology	Dan Green (UCSD), Joshua Ruderman (NYU), Ben Safdi (UM), Jessie Shelton (UIUC)
TF10:	Quantum Information Science	Simon Catterall (Syracuse), Roni Harnik (FNAL), Veronika Hubeny (UCD)
TF11:	Theory of Neutrino Physics	André de Gouvêa (Northwestern), Irina Mocioiu (Penn State), Sair Pastore (Washington U.), Louis Strigari (TAMU)

Liaisons to Other Frontiers

Energy Frontier:	Laura Reina (Florida State)
Neutrino Physics Frontier:	Irina Mocioiu (Penn State) and Kaladi S. Babu (OSU)
Rare Processes and Precision Frontier:	Alexey Petrov (Wayne State)
Cosmic Frontier:	Flip Tanedo (UC Riverside)
Accelerator Frontier:	Lian-Tao Wang (U Chicago)
Computational Frontier:	Steven Gottlieb (Indiana)
Community Engagement Frontier:	Devin Walker (Dartmouth)

LOIs in many different directions!

Letters of Interest related to other frontiers....

Large-Scale Structure at high redshift: a probe of fundamental physics

Quantum Computing for HEP Theory and Phenomenology

Jets and Jet Substructure at Future Colliders

Letter of Interest for Snowmass 2021

The BOOST community¹

Precision theory inputs for $|V_{cb}|$ and LFUV observables
Snowmass 2021 LOI

**Global SMEFT Fits Including Theory Uncertainties:
A Snowmass Letter of Interest**

... and specifically for the theory frontier

**Theory Needs for FCC-ee Part II: New methods for SM
calculations**

Improvements in parton shower algorithms

Perturbative calculations: elliptic contributions

**Expectations for SUSY from the landscape:
a Snowmass 2021 TF01/TF08 Letter of Intent**

Early Career Contacts and Liaisons

Unique opportunity for early career theorists to make a difference!

Main points of contact:

Sam Homiller (shomiller@gmail.com), Seth Koren (sethk@uchicago.edu),
Soubhik Kumar (soubhik@terpmail.umd.edu), Robert McGehee (rmcgehee@umich.edu)

- TF01: Shanna N Dobson, [redacted]
- TF02: Da Liu, [redacted]
- TF03: [redacted]
- TF04: Da Liu, Julio Parra-Martinez
- TF05: William Jay, [redacted]
- TF06: Joshua Isaacson, [redacted]
- TF07: Sam Homiller, [redacted]
- TF08: Robert McGehee, Sam Homiller, Yu-Dai Tsai
- TF09: Robert McGehee, Soubhik Kumar, Yu-Dai Tsai
- TF10: Yingying Li, [redacted]
- TF11: Kevin Kelly, Vishvas Pandey, Manibrata Sen, Julia Gehrlein

**Lots of room for
volunteers to
help facilitate
more activity!**

Special thanks to Yu-Dai Tsai for getting us organized initially!

How to Participate:

Join Meetings:

Community Planning Meeting: October 5-9, 2020, Virtual

Theory Frontier Conference: March 17-19, 2021 @ KITP

Main Theory Frontier event — showcase theory developments, consolidate activities in advance of summer studies, cultivate interactions between theorists working across frontiers

Community Summer Study: July 11-20, 2021 @ Seattle

Contributed Papers and LOIs:

Letters of Interest for the TF *do not have August 31 deadline**

*though it still applies if you want it cross-listed with other frontiers)

Contributed Papers: Whitepapers on specific scientific areas, presenting new results on relevant topics, and reasoned expressions of priorities

Let us know if we can help organize contributions for LOIs or Whitepapers!

Get Involved!

A new frontier needs new ideas!

Join us on Slack:

- **#sec-th**
- #theory_frontier_topics
- #tfXX-groupname (e.g., #tf01-strings_gravity)

Feel free to reach out directly to the conveners or early career liaisons!

Listserv: SNOWMASS-THEORY-FRONTIER-GROUP@fnal.gov

(see <https://snowmass21.org/theory/start> for sign-up instructions and contact info for the topical groups)

Look out for Google Forms to express interest in groups!

(or reach out to conveners if you can't find one!)

Let us know the best way to help advance your ideas!