

Energy Frontier Activities and Planning

Snowmass Community Planning Meeting, Oct 5-8, 2020

Laura Reina (FSU)

Meenakshi Narain (Brown U.)

Alessandro Tricoli (BNL)

We would like to collect some information

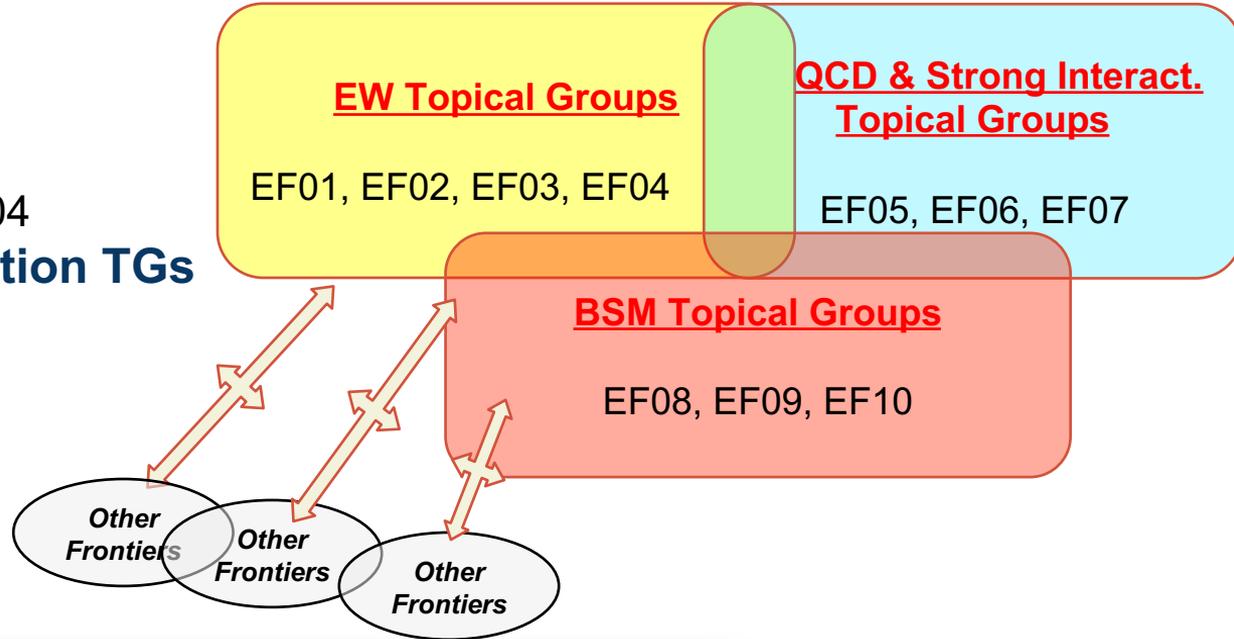
- Zoom poll: Today's participant demographics
 - Please select your professional level
 - Student, Postdoc, Junior faculty/scientist, Mid Career/Senior faculty /scientist
 - Theorist OR Experimentalist?
 - New to EF activities?
 - I am new to the EF group
 - I am already participating in the topical group activities
- Please share your comments about the EF activities and organization, how are we doing?
 - We would like to hear all aspects.
 - While we always like to hear how we can make things better moving forward, we are always delighted to hear words of praise as well!
 - <https://docs.google.com/forms/d/e/1FAIpQLScFq5o6wPqC9qTPtqryclcaaZY22HF77Zf59jLiNqa2uebHw/viewform>

Some of the questions in the survey

- We invite you to share your thoughts on the CPM meeting.
- As an EF participant, we would like to hear your thoughts on the balance of the joint sessions at the CPM meeting.
- Please share any comments you may have on the topical group organization
- One of our goals is to engage early career physicists effectively in the EF activities. We invite you to share ideas on how best we can do this. If you are a PI, we would like to understand how can we enable participation and presentations by postdocs and students in your group. In you are a early career member, please let us know how we can help with your participation.

Topical Group Activities

- **Electroweak TGs**
 - EF01, EF02, EF03, EF04
- **QCD and Strong Interaction TGs**
 - EF05, EF06, EF07
- **BSM TGs**
 - EF08, EF09, EF10



Multiple Ongoing Activities

- See [Wiki pages](#) for links to Google forms with *calls for inputs/contributions*
- Follow examples of ongoing activities in Bi-Weekly and ad-hoc Joint meetings
 - See [indico meeting agendas](#) for details

EW Physics

EF01 Convenors:

Sally Dawson, Andrey Korytov, Caterina Vernieri

EF01 - Higgs boson properties and couplings

- Higgs mass and width
- Higgs couplings to SM gauge bosons and fermions
- Higgs production modes: inclusive and diff. measurements (incl. $t\bar{t}H$)
- HH production (includes resonant production)
- Higgs self-coupling
- **Higgs rare decays**
- **Anomalous couplings (including CP violation)**
- **Inputs to the Global Fit**

EW Physics

EF02 - Higgs boson as a portal to new physics

- 1) Higgs as origin of EWSB, naturalness/fine-tuning portal to new physics, 2) Higgs and flavor, 3) Higgs and EW phase transition.
 - a. BSM Higgs: 2HDM, SUSY Higgs ($A \rightarrow Zh$, LFV, Charged Higgs etc.), extra scalars, exotic decays, mono-Higgs searches
 - b. **Composite Higgs (with BSM groups)**
 - c. **Effect on Higgs couplings to fermions/bosons and Higgs width from extending the scalar sector**
 - d. **Flavor violating Higgs production and decays**
 - e. $H \rightarrow hh$
 - **Higgs rare decays**

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EF02 Convenors:

Isobel Ojalvo, Patrick Meade

EW Physics

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$t\bar{t}H$

EF03 Convenors:

Reinhard Schwienhorst, Doreen Wackerath

EF03 - Heavy flavor and top quark physics

- Heavy flavor production (top, bottom, and charm)
- Top-quark properties (mass, couplings) and diff. measurements
- New top-quark production modes and rare decays
- Detection algorithms for top-quark identification

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EF04 - Precision physics and constraining new phys.

- Precision fits of SM observables
- Multi-boson signatures, and VBF, VBS processes
- (SM)EFT analyses of EWPO, Higgs, and top observables
- Correlations among exp. and theory uncert.,
- Modeling of EW and QCD uncert., and their combination

EF04 Convenors:

Alberto Belloni, Ayres Freitas, Junping Tian

EF03 - Heavy flavor and top quark physics

$t\bar{t}H$

- Heavy flavor production (top, bottom, and charm)
- Top-quark properties (mass, couplings) and diff. measurements
- New top-quark production modes and rare decays
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QCD and Strong Interaction Physics

EF05 Convenors:

Michael Begel, Stefan Hoeche, Michael Schmitt

EF05 - Precision QCD

- Jet and jet substructure
- Higher-order effects and impact on precision QCD physics
- Strong coupling constant and its running
- Quark masses
- V(+jets) boson production
- Accuracy of future MC event generators
- **Impact of PDF fits and PDF-sensitive measurements**

QCD and Strong Interaction Physics

EF06 Convenors:

Huey-Wen Lin , Christophe Royon, Pavel Nadolsky

EF05 - Precision QCD

- Jet and jet substructure
- Higher-order effects and impact on precision QCD physics
- Strong coupling constant and its running
- Quark masses
- W/Z(+jets) boson production
- Accuracy of future MC event generators
- **Impact of PDF fits and PDF-sensitive measurements**

EF06 - Hadronic structure and forward QCD

- PDF Fits and Generalized PDF
- Hadronic structure
- Forward and soft QCD
- **Hadron spectroscopy (with RF)**

QCD and Strong Interaction Physics

EF07 - Heavy Ions

- Physics of heavy ions (HI) and its impact on EF
- Physics at electron-ion colliders
 - a. **EW physics in HI (with EW groups)**
 - b. **BSM Searches in HI (with BSM groups)**
 - c. **Jets in HI**

EF07 Convenors:

Yen-Jie Lee, Swagato Mukherjee

EF05 - Precision QCD

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EF06 - Hadronic structure and forward QCD

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BSM Physics

EF08 - Model Specific explorations

- SUSY, Extra Dimensions, and Leptoquarks etc.
- Sensitivity, Reinterpretations of sensitivities (e.g. a long-lived particle as a Higgsino)
- Model parameter scans and comparisons with precision measurements (e.g. pMSSM scans)
 - a. SUSY: Strong (inclusive searches / gluino / squark), 3rd gen (stop, sbottom), EWKino, singlino, "Pure" higgsino, R-parity violating SUSY
 - b. Blackhole Multijets, RS Gravitons
 - c. pMSSM or other scans
 - d. **Model-specific searches for excited fermions**

EF08 Convenors:

Jim Hirschauer, Elliot Lipeles, Nausheen Shah

BSM Physics

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EF09 Convenors:

Tulika Bose, Zhen Liu, Simone Pagan Griso

EF09 - More General explorations

- New Fermions (Top partners, Excited Quarks/Leptons, Sterile Neutrinos etc.)
- New Bosons (W' , Z' , diboson-resonances etc.)
- Dark/Hidden sectors (ALP, dark photons etc.)
- **Long-live particle signatures**
- **BSM interplay with EFT (with EF04)**

BSM Physics

EF10 Convenors:

Caterina Doglioni, LianTao Wang

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EF10 - Dark Matter at colliders

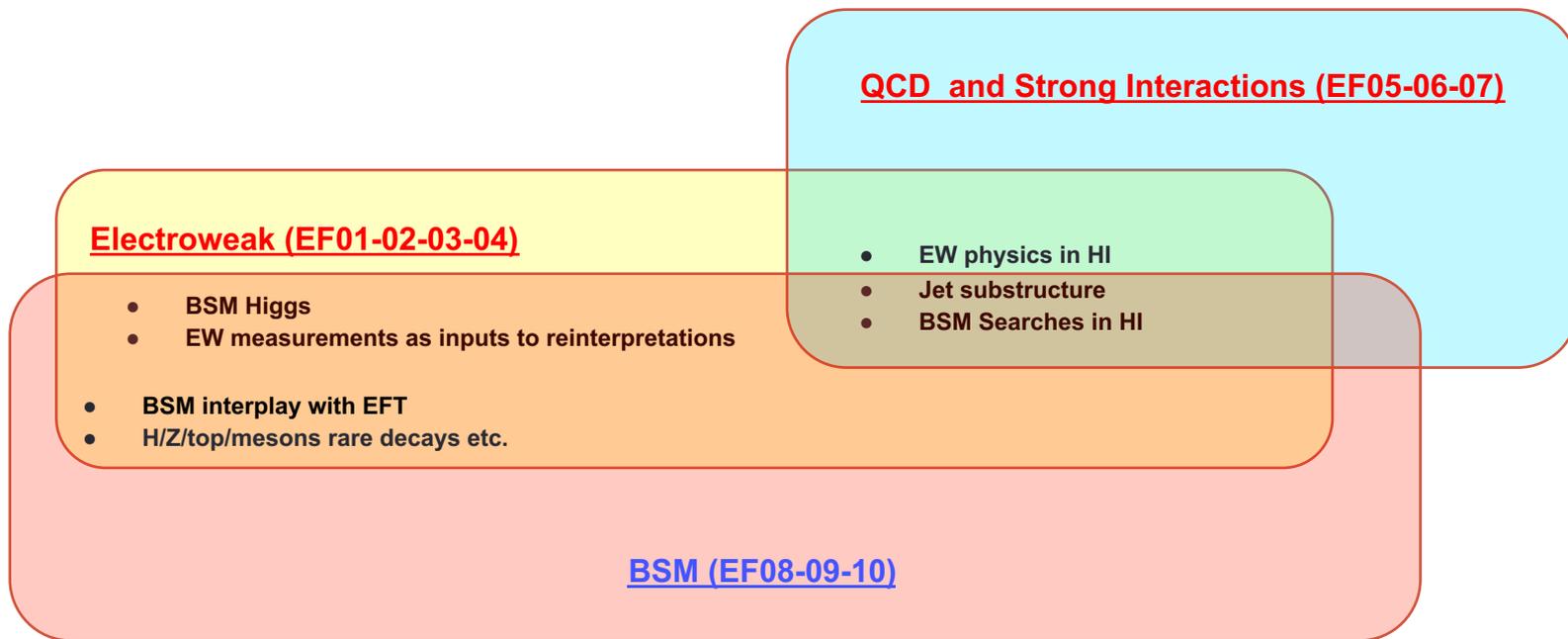
- Dark Matter and Dark Sector searches at EF colliders
- WIMP models: ew multiplet, vector/scalar mediator simplified models, and Higgs portal
- Models targeting different DM masses and couplings wrt WIMP, and portals through dark photon and generic dark scalar/pseudoscalar
- DM interpretation of searches for visible decays of mediators
- **Complementarity with fixed target, direct detection (with CF & RF)**
- **Projections for FASER/CODEX-b/Mathusla, etc. (with RF)**
- **H/Z/top/mesons rare decays etc. (with EW groups)**
- **mono-X searches, MET Signatures**
 - Long-live particle signatures

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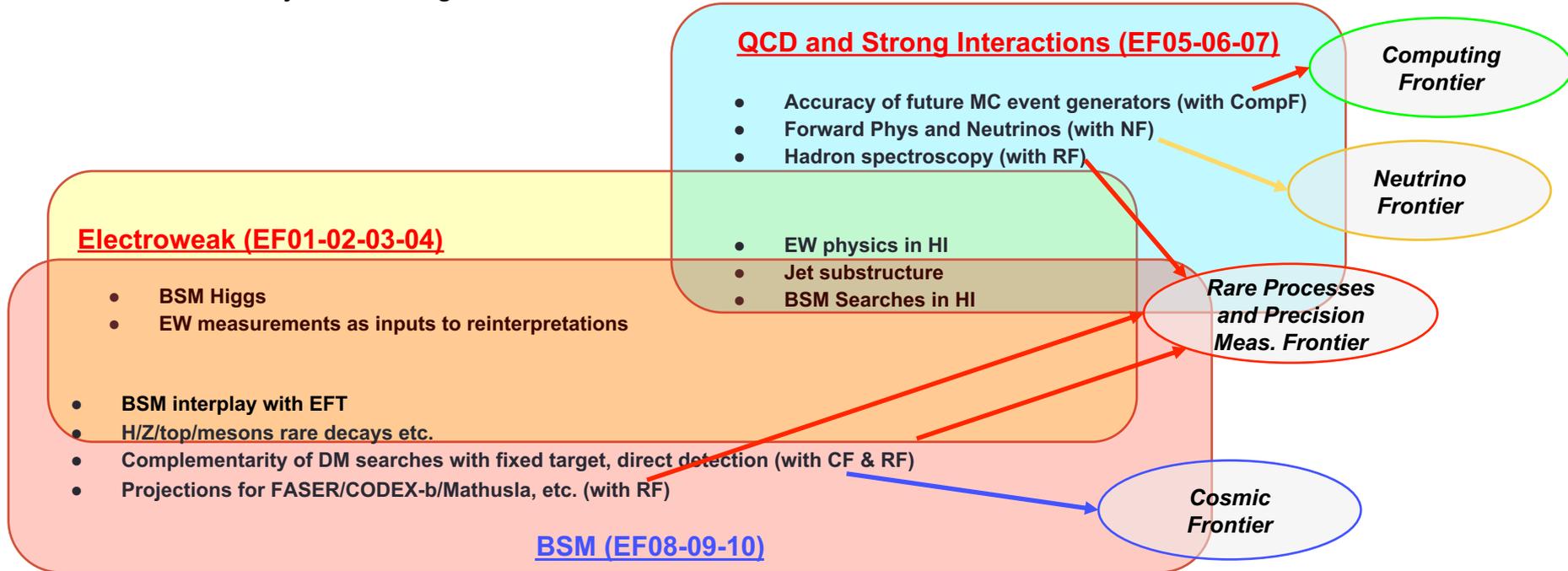
Synergies and Overlaps

- **Several synergies between Topical Groups and other Frontiers**
- **All groups commit to working together to minimise duplication and allow full sharing of information**
 - In general a topic is 'owned' by a TG, but information is shared among the other relevant groups
 - Plans for joint meetings



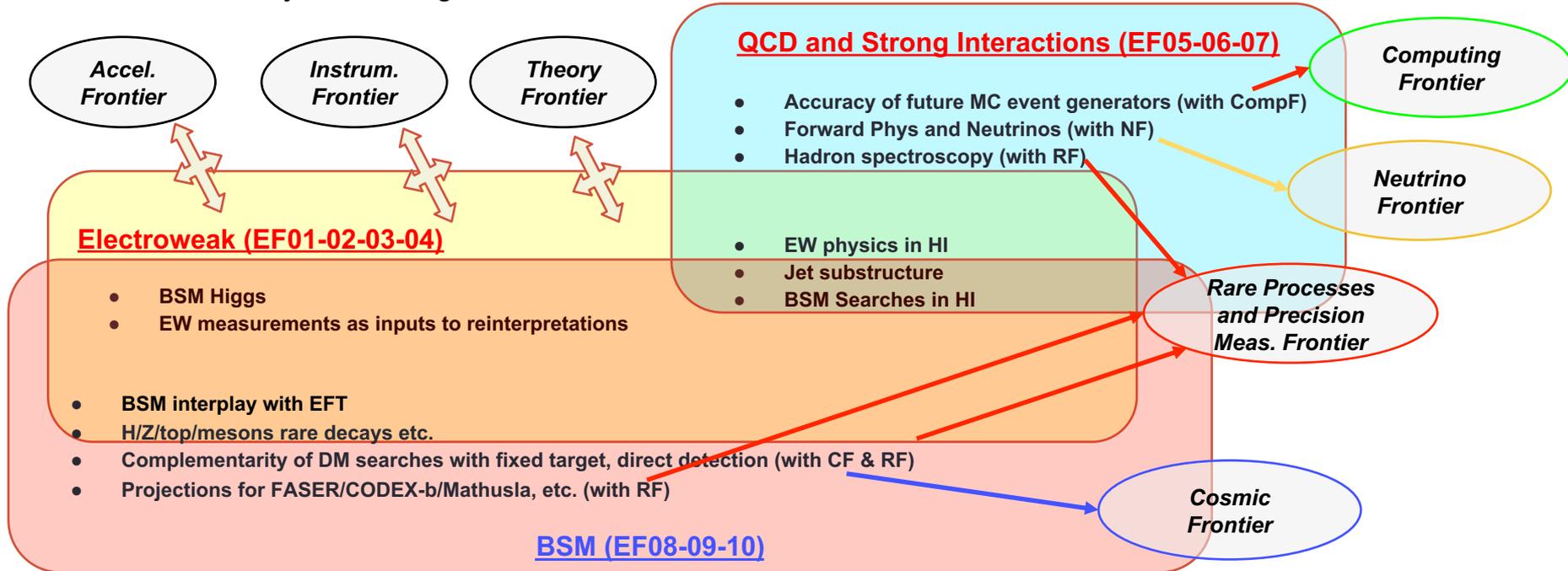
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Accelerator Benchmark Parameters

Snowmass 2021 Energy Frontier Collider Study Scenarios

Collider	Type	\sqrt{s}	P [%] e^-/e^+	L_{int} ab^{-1}
HL-LHC	pp	14 TeV		6
ILC	ee	250 GeV	$\pm 80 / \pm 30$	2
		350 GeV	$\pm 80 / \pm 30$	0.2
		500 GeV	$\pm 80 / \pm 30$	4
		1 TeV	$\pm 80 / \pm 20$	8
CLIC	ee	380 GeV	$\pm 80 / 0$	1
		1.5 TeV	$\pm 80 / 0$	2.5
		3.0 TeV	$\pm 80 / 0$	5
CEPC	ee	M_Z		16
		$2M_W$		2.6
		240 GeV		5.6
FCC-ee	ee	M_Z		150
		$2M_W$		10
		240 GeV		5
		$2 M_{\text{top}}$		1.5

Snowmass 2021 Energy Frontier Collider Study Scenarios

Collider	Type	\sqrt{s}	P [%] e^-/e^+	L_{int} ab^{-1}
FCC-hh	pp	100 TeV		30
LHeC	ep	1.3 TeV		1
FCC-eh	ep	3.5 TeV		2
muon-collider (higgs)	$\mu\mu$	125 GeV		0.02
High energy muon-collider	$\mu\mu$	3 TeV		1
		10 TeV		10
		14 TeV		20
		30 TeV		90

Note for muon-collider: It is important to note that the plan is not to run subsequently at the various c.o.m etc. These are reference points to explore and assess the physics potential and technology. The luminosity can be varied to determine how best to exploit the physics potential.

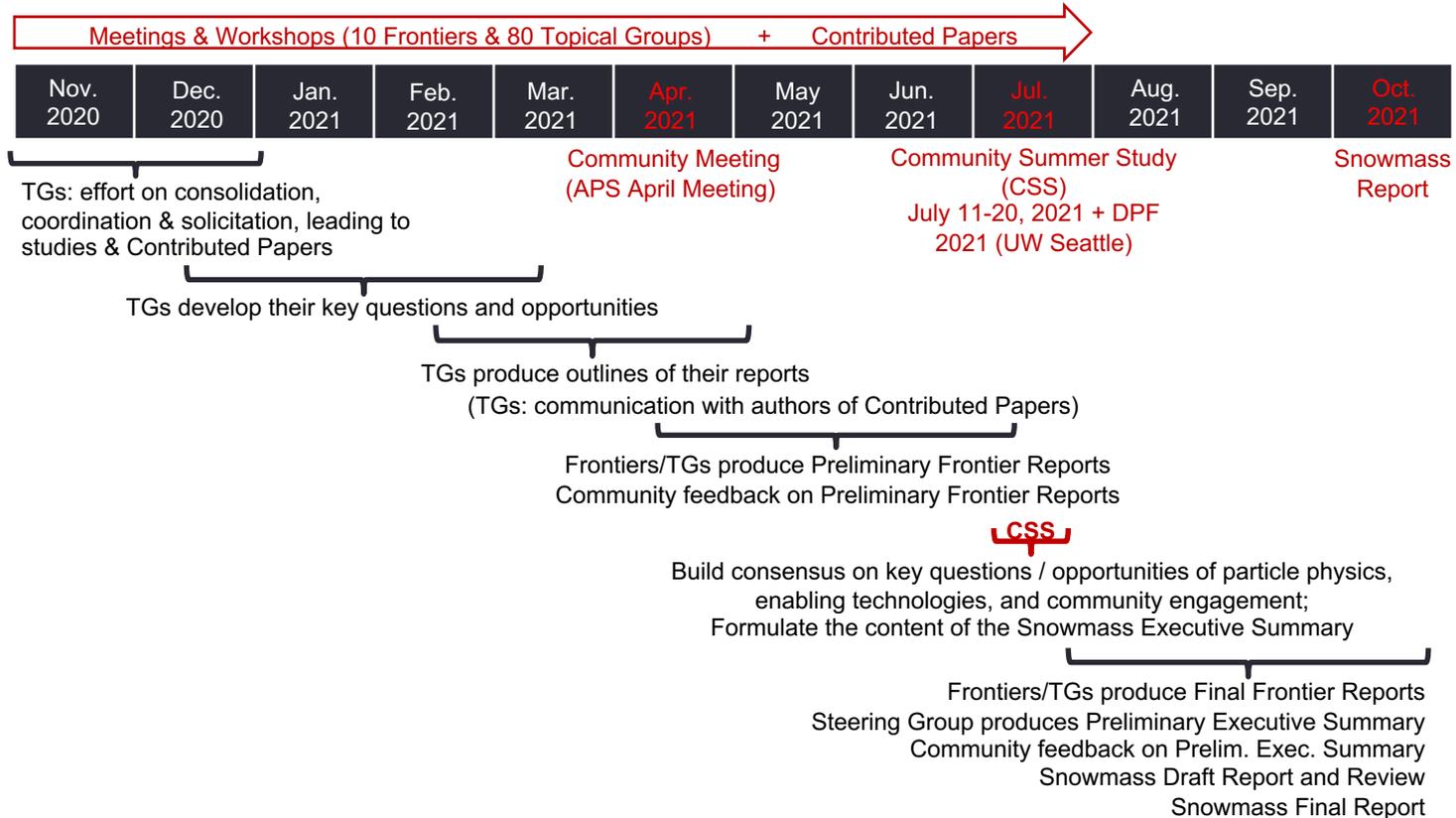
Other options to explore:

- Muon collider at a very high energy (>30 TeV?), other energies, need to consolidate the growing list of COM
- FCC pp >200 TeV? and ~75 TeV documenting sensitivity loss
- Very high energy e+e- collider
- gamma-gamma collider [need to understand energy/luminosities]

Update the table with input provided at this CPM

Preliminary Snowmass Timeline / Process

Starting point for discussion with the community during CPM



Energy Frontier Specific Preliminary Snowmass Timeline / Process

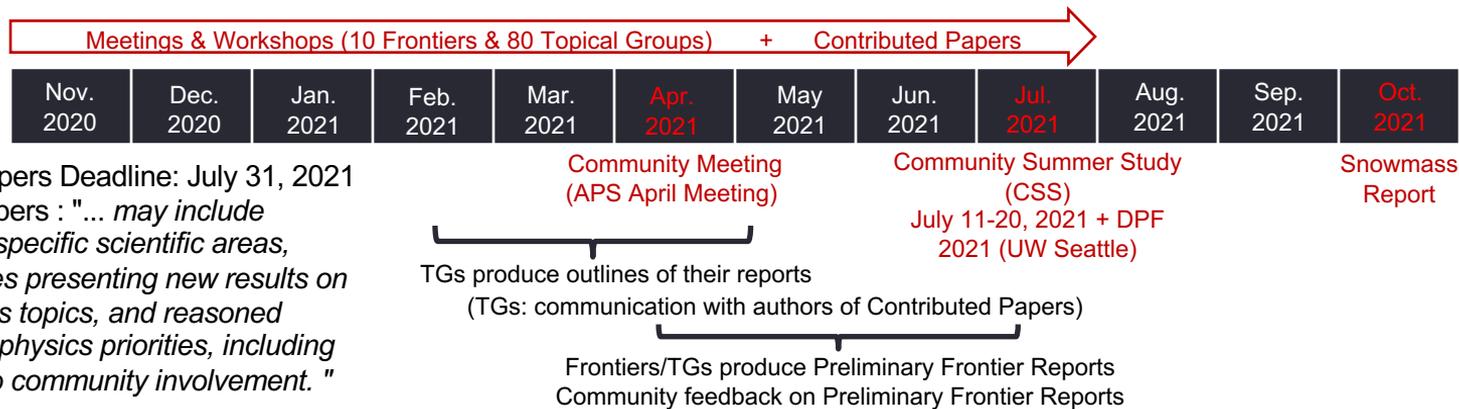
Starting point for discussion with the community during CPM



- **This is an opportunity for EF participants to engage in the activities of the Topical Groups, and present /discuss their work**
- Topical Group and EF Conveners have been developing focus/key questions and preparing a summary of the existing physics landscape as a starting point of the report.
- The topical groups may need input from their community to include a brief description of proposed/ongoing work.
- This is also an opportunity to identify any gaps in physics topics and work on them.

Energy Frontier Specific Preliminary Snowmass Timeline / Process

Starting point for discussion with the community during CPM

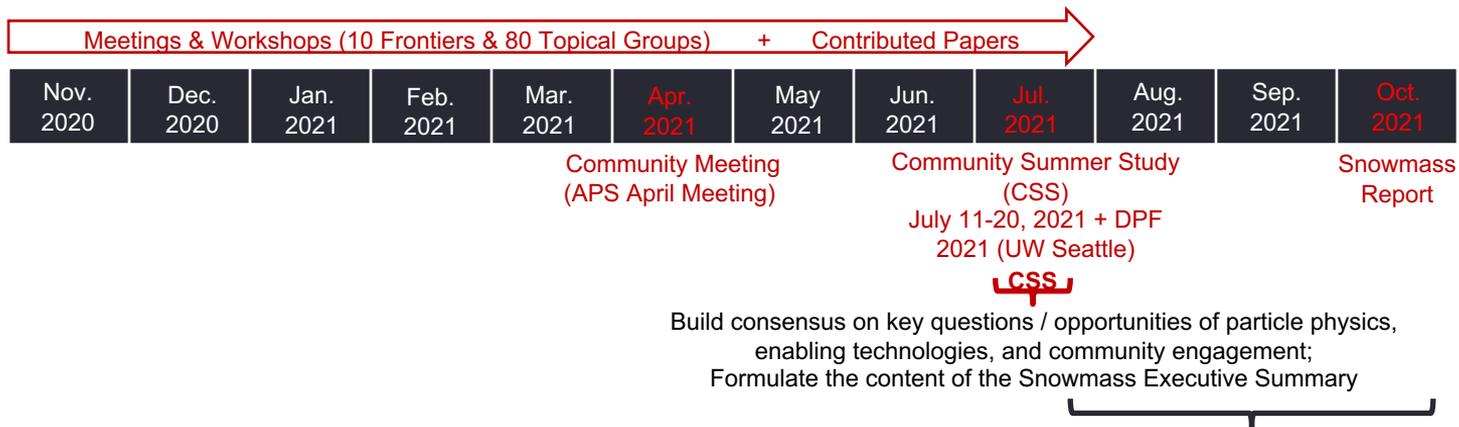


Contributed Papers Deadline: July 31, 2021
 Contributed papers : "... may include documents on specific scientific areas, technical articles presenting new results on relevant physics topics, and reasoned expressions of physics priorities, including those related to community involvement. "

- **This is an opportunity for EF participants to make sure their work is reflected in the report.**
- **During Spring, the EF will announce the mechanism for collection of summaries of results to be included in the report by May 2021.**
- The TG conveners will assemble the report until July workshop. The TG conveners will start from the input provided by contributors, and edit the input to match the style and length of the report.
- We will solicit feedback on this preliminary report from the community to verify that their work has been summarized correctly.

Energy Frontier Specific Preliminary Snowmass Timeline / Process

Starting point for discussion with the community during CPM



Frontiers/TGs produce Final Frontier Reports
 Steering Group produces Preliminary Executive Summary
 Community feedback on Prelim. Exec. Summary
 Snowmass Draft Report and Review
 Snowmass Final Report

Preliminary Snowmass Report Structure

Starting point for discussion with the community during CPM

Preliminary
Report Structure:
Adopting Snowmass 2013

Executive Summary

(~50 pages)

Introduction

A few pages from each Frontier

Frontier Report

Frontier Summary

(20~50 pages)

Topical Group Reports

(20~50 pages per TG)

Contributed Papers as References



Intensity Frontier

[Snowmass 2013](#)

Chapter 2: Intensity Frontier

Conveners: J.L. Hewett and H. Weerts

[Working Group Summary \(arXiv:1401.6077\)](#)

Subgroup Reports:

- | | | |
|-----|--|---------------------------|
| 12. | Neutrinos | 1310.4340 |
| 13. | Baryon Number Violation | 1311.5285 |
| 14. | Charged Leptons | 1311.5278 |
| 15. | Quark Flavor Physics | 1311.1076 |
| 16. | Nucleons, Nuclei, and Atoms | 1312.5416 |
| 17. | New Light Weakly Coupled Particles | 1311.0029 |

Contributed Papers:

General:

- | | | | |
|-----|----------------------------|--|--------------------------------|
| 001 | K. Lesko | Why the US Needs a Deep Domestic Research Facility: Owning rather than Renting the Education Benefits, Technology Advances, and Scientific Leadership of Underground Physics | 1304.0402 (PL) |
| 019 | S. Holmes, <i>et al.</i> | Project X: A Flexible High Power Proton Facility | 1305.3809 (PL) |
| 021 | S. Glashow | Particle Physics in the United States: A Personal View | 1305.5482 (PL) |
| 024 | V. Shiltsev, <i>et al.</i> | Issues and R&D Required for the Intensity Frontier Accelerators | 1305.6917 (PL) |
| 055 | A. Kronfeld, <i>et al.</i> | Project X: Physics Opportunities | 1306.5009 (PL) |
| 056 | S. Holmes, <i>et al.</i> | Project X: Accelerator Reference Design | 1306.5022 (PL) |

Energy Frontier Workshops

- We are planning energy frontier workshops in the spring/summer
 - April/May:
 - To check the status of studies for the final report.
 - To help with collating the summaries of contributed papers.
 - June:
 - Review the inputs to the draft report prior to the July 2021 CSS workshop
- Topical group workshops are also being planned
- Joint workshop of EF with AF and TF is being discussed.

Conclusion

- Thank you for your continued participation in Energy Frontier activities and helping us chart our vision for the future!
- Your engagement is an essential ingredient in defining the major questions and the colliders.
- We appreciate your feedback:
- <https://docs.google.com/forms/d/e/1FAIpQLScFq5o6wPqC9qTPtqryclcaaZY22HF77Zf59jLiNqa2uebHw/viewform>