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Snowmass'21 Accelerator Frontier: Goals and Progress

Vladimir Shiltsev, Fermilab

on behalf of AF conveners: S.Gourlay, T.Raubenheimer and V.S.

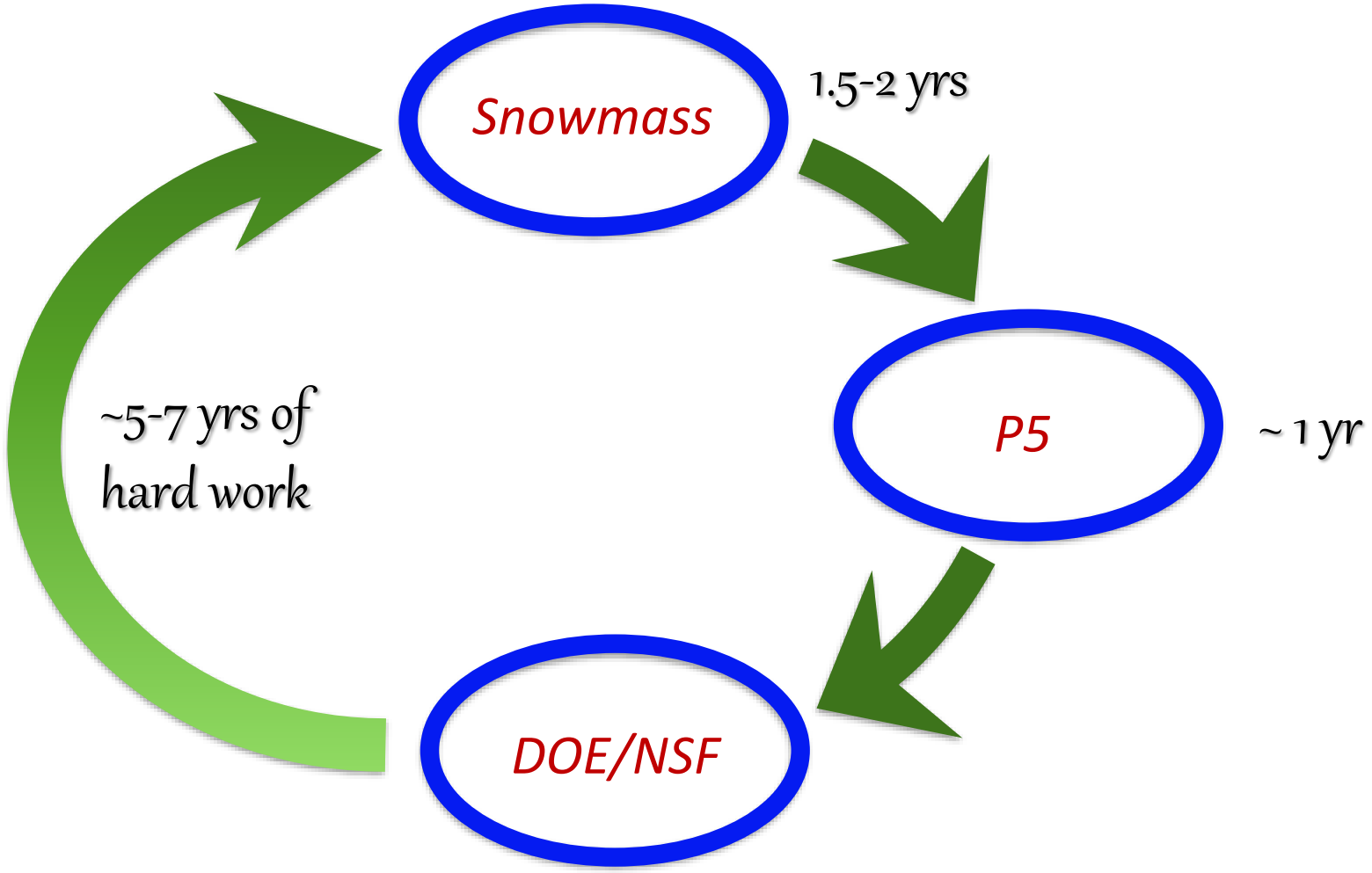
IAS/HKUST Program on HEP (virtual), Jan 21, 2021

Snowmass'2021

- What *Snowmass* is
- Organization:
  - Committees, Frontiers and Topical Groups
- Timeline
- Accelerator Frontier
- Topical Groups and Initiatives:
  - Implementation Task Force
  - Muon Collider Forum
  - Physics Limits of Ultimate Beams
- Questions?

What *Snowmass* is :

"Snowmass is a particle physics community study"



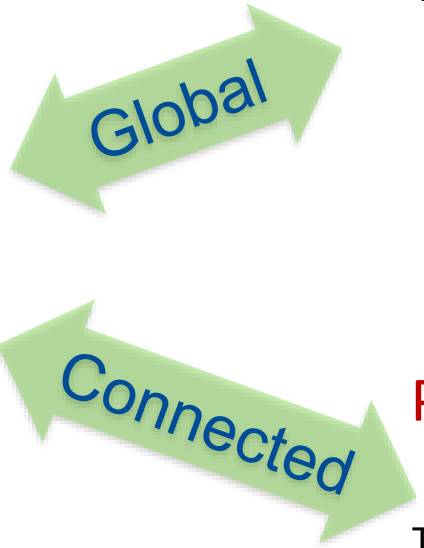
https://www.snowmass21.org/

U.S. Strategic Planning Process for Particle Physics

Community-Driven Science Study (a.k.a. "Snowmass")

Define the most important questions for the field;
Identify promising opportunities to address them

Organized by DPF
w/ related divisions (DPB, DNP, DAP, DGRAV)



Particle Physics is global:

The Snowmass process involves communities and plans from other regions

Particle Physics is not isolated:

The Snowmass process involves communities and plans from related fields (Accelerator, Nuclear, Astro, Gravitational, AMO, …)

Snowmass'21 Organization

Advisory Group
(incl. Steering Cmtee)

Snowmass Frontiers

Liasons **Snowmass Young**

Topical Groups

Community

Fermilab

Snowmass'21 Advisory Group

- DPF Executive Committee

2021 Steering Group

  - Chair: Tao Han
  - Chair-elect: Joel Butler
  - Vice Chair: Sekhar Chivukula
  - Past Chair: Young-Kee Kim
  - Ex Officio: Prisca Cushman
  - Secretary/Treasurer: Mirjam Cvetic
  - Councilor: Elizabeth Simmons
  - Member-at-Large: Natalia Toro
  - Member-at-Large: Andre de Gouvea
  - Member-at-Large: Mary Bishai
  - Member-at-Large: Lauren Tompkins
  - Member-at-Large: Mayly Sanchez
  - Member-at-Large: Gordon Watts
  - Early Career Member-at-Large: Julia Gonski

- Editor and Communication
  - Editor – Michael Peskin
  - Communication – Bob Bernstein

- Representatives from other Divisions
  - DPB: Sergei Nagaitsev
  - DNP: Yury Kolomensky
  - DAP: Glennys Farrar
  - DGRAV: Nicolas Yunes

- Representatives from the Int. Community
  - Africa / Middle East
    - Azwinndini Muronga, Nelson Mandela Metropolitan Univ, South Africa
  - Asia / Pacific
    - Atsuko Ichikawa, Kyoto University, Japan
    - Xinchou Lou, IHEP, China
  - Canada
    - Heather Logan, Carleton University, Canada
  - Europe / Russia
    - Val Gibson, Cavendish Laboratory, UK
    - Berrie Giebels, CNRS, France
  - Latin America
    - Claudio Dib, Universidad Tecnica Federico Santa Maria, Chile

Snowmass'21 Frontier Conveners

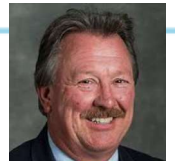
Energy Frontier


Meenakshi Narain (Brown U)

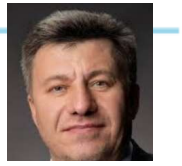

Laura Reina (FSU)


Alessandro Tricoli (BNL)

Accelerator Frontier


Steve Gourlay (LBNL)


Tor Raubenheimer (SLAC)


Vladimir Shiltsev (FNAL)

Frontiers in Neutrinos


Patrick Huber (Virginia Tech)


Kate Scholberg (Duke U.)


Elizabeth Worcester (BNL)

Instrumentation Frontier


Phil Barbeau (Duke)


Petra Merkel (FNAL)


Jinlong Zhang (ANL)

Frontiers in Rare & Precision


Marina Artuso (Syracuse U.)


Alexey Petrov (Wayne State U.)


Bob Bernstein (FNAL)

Computational Frontier


Steven Gottlieb (Indiana U.)


Ben Nachman (LBNL)


Oliver Gutsche (FNAL)

Cosmic Frontier


Aaron Chou (Fermilab)


Marcelle Soares-Santos (U.Michigan)


Tim Tait (UC Irvine)

Underground Facilities and Infrastructure Frontier


Laura Baudis (U. Zurich)


Jeter Hall (SNOLAB)


Kevin Lesko (LBNL)


John Orrell (PNNL)

Theory Frontier


Nathaniel Craig (UCSB)


Csaba Csaki (Cornell)


Aida El-Khadra (UIUC)

Community Engagement Frontier


Kétévi Assamagan (BNL)


Breese Quinn (Mississippi)

Snowmass'21: Frontiers and Topical Groups

10 Frontiers	80 Topical Groups
Energy Frontier	Higgs Boson properties and couplings, Higgs Boson as a portal to new physics, Heavy flavor and top quark physics, EW Precision Phys. & constraining new phys., Precision QCD, Hadron Structure and forward QCD, Heavy Ions, Model specific explorations, More general explorations, Beyond Colliders
Frontiers in Neutrino Physics	Neutrino Oscillations, Sterile Neutrinos, Beyond the SM, Neutrino Properties, Neutrino Cross Sections, Nuclear Safeguards and Other Physics, Artificial Neutrino Sources, Neutrino Detectors
Frontiers in Rare Processes & Precision Measurements	Weak Decays of b and c, Strange and Charm Decays and Small Experiments. Baryon and Lepton Number Violation, Dark Sector at Low Energies, Hadron spectroscopy
Cosmic Frontier	Dark Matter: Particle Dark Matter: Cosmic Probes, Dark Energy & Cosmic Acceleration: Dark Energy & Cosmic Acceleration: Cosmic Dawn & Before, Dark Energy & Cosmic Acceleration: Diversity of Probes and New Facilities
Theory Frontier	Gravity, black holes, Effective field theory techniques, CFT and formal QFT, Scattering Amplitudes, Gauge theory, Theory techniques for precision physics, Collider phenomenology, BSM model building, Particle physics and cosmology, Quantum information science, Theory of Neutrino Physics
Accelerator Frontier	Beam Physics and Accelerator Education, Accelerators for Neutrinos, Accelerators for Electroweak and Higgs Physics, Multi-TeV Colliders, Accelerators for Physics Beyond Colliders & Rare Processes, Advanced Accelerator Concepts, Accelerator Technology R&D: RF, Magnets, Targets/Sources
Instrumentation Frontier	Quantum Sensors, Photon Detectors, Solid State Detectors & Tracking, Trigger and DAQ, Micro Pattern Gas Detectors, Calorimetry, Electronics/ASICS, Noble Elements, Cross Cutting and System Integration, Radio Detection
Computational Frontier	Experimental Algorithm Parallelization, Theoretical Calculations and Simulation, Machine Learning, Storage and processing resource access (Facility and Infrastructure R&D), End user analysis
Underground Facilities and Infrastructure Frontier	Underground Facilities for Neutrinos, Underground Facilities for Cosmic Frontier, Underground Detectors
Community Engagement Frontier	Applications & Industry, Career Pipeline & Development, Diversity & Inclusion, Physics Education, Public Education & Outreach, Public Policy & Government Engagement

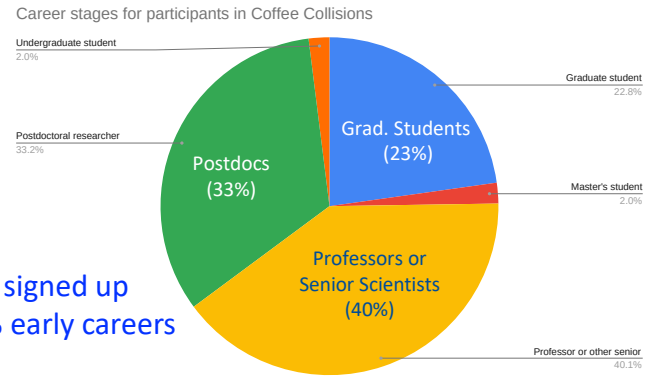
30 Frontier conveners, ~250 Topical Group conveners, >40 Inter-Frontier Liaisons, ~25 Early Career Liaisons

Snowmass Young (Early Careers)

- The Snowmass 2021 process is towards a long-term strategic plan
  - Voices of early career members are critically important
  - Undergrad & grad students; postdocs, early-career faculty, engineers (<~10 years post-PhD)
- Snowmass Young Representatives
  - Based on > 250 nominations*!!*
- Goals
  - Snowmass: Represent early careers and promote their engagement
    - Snowmass coordination: 2-3 Liaisons per Frontier
  - Build a long-term HEP early career community
    - Survey of the early career membership
    - In-reach: Professional development, …
    - EDI (diversity, equity, and inclusion)
    - Long-term organization
- Snowmass Early Careers Wiki
  - https://snowmass21.org/start/young

In-reach Initiatives:

- Monthly big questions colloquium series
- "Coffee Collisions" to create new connections across career stages via for 1-on-1 meetings



~200 signed up
~60% early careers

Snowmass'21 Approximate Timeline

- 2019
  - Announcement (October'19), organization of Frontiers
- 2020
  - Organization of Topical Groups
  - Submission of Letters of Interest (LoIs)
  - Virtual *Community Planning Meeting* October 5-8
- 2021
  - Work in TGs/Frontiers toward White paper
  - Snowmass'21 at APS 2021 April & DPF 2021 meetings
- 2022
  - White paper submissions, preliminary TG & F reports
  - *Community Summer Study* – July'22
  - Final TG/Frontier reports
  - **Snowmass Book (SG) – October'22**

Snowmass 2021 Report Structure (Preliminary)

- **Snowmass Summary for Public**
  - 2 pages
- **Snowmass Summary Report**
  - ~50 pages
    - Executive Summary: ~10 pages
    - Introduction
    - 10 Frontier Executive Summaries
    - Executive Summaries of Multi-Frontier Topics
    - Conclusion
- **Snowmass Book**
  - ~500 pages
    - Snowmass Summary Report (~50 pages)
    - Frontier Summaries (~400 pages with 10 Frontiers)
    - Multi-Frontier Topic Summaries (~50 pages)
- **Topical Group Reports**
  - Topical Group Reports: short reports
- **Reports of Multi-Frontier Topics**
  - Multi-Frontier Topics spanning multiple Frontiers.
  - Each Multi-Frontier Topic Summary: ~10 page

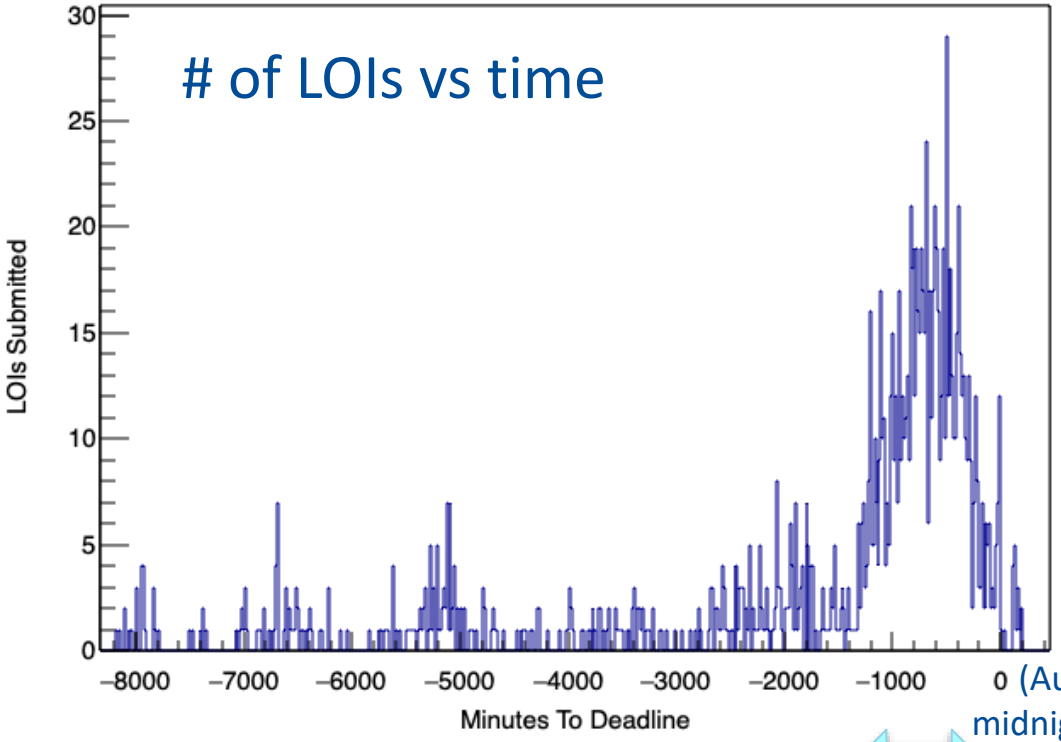
(Written by TG members including early careers)

- **Contributed Papers**
  - References

(Written by the community including early careers)

2020 Highlights: *Letters of Interests* (2 pages)

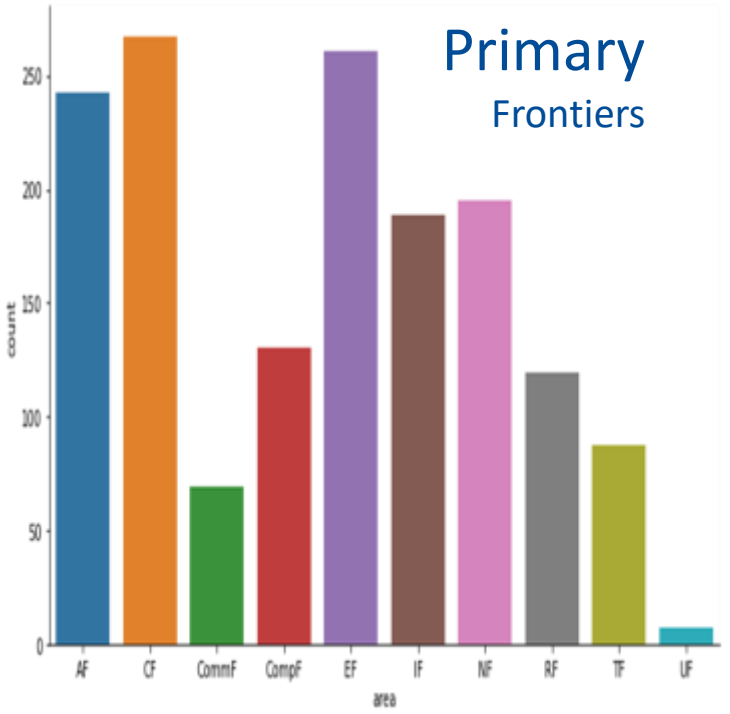
1,574 in total: submitted before August 31, 2020
Many LOIs – multiple frontiers



(Credit: Sam Hedges)

(Aug. 31 midnight in Hawaii)

20 hours



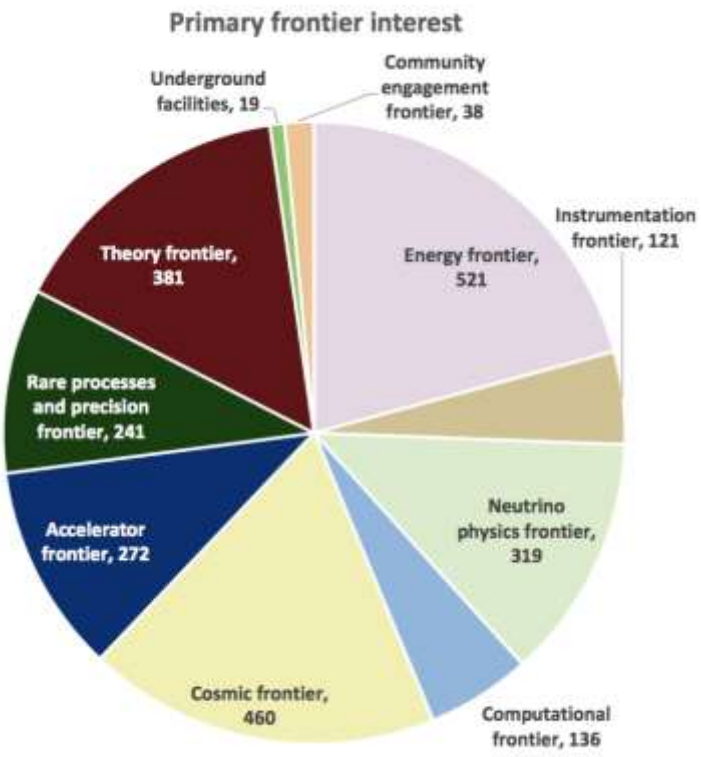
(Credit: Gordon Watts)

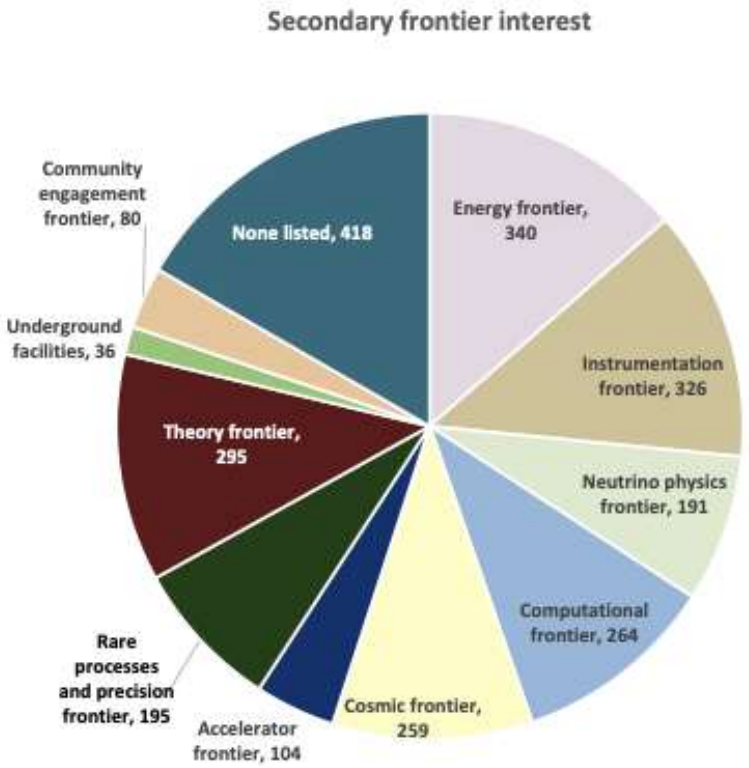
Snowmass *Community Planning Meeting*: Oct 5-8, 2020

~3,000 participants

~650 outside the North America Time Zone

(Note that 11am-4pm U.S. Central time was inconvenient – very inconvenient for many countries)





Accelerator Frontier

- **Co-Conveners**

  Steve Gourlay (LBNL)
  Tor Raubenheimer (SLAC)
  Vladimir Shiltsev (FNAL)



- **Description**

  The Accelerator Frontier activities include discussions on high-energy hadron and lepton colliders, high-intensity beams for neutrino research and for the “Physics Beyond Colliders”, accelerator technologies, science, education and outreach as well as the progress of core accelerator technology, including RF, magnets, targets and sources. Participants will submit LoI, contributed papers, take part in corresponding workshops and events, contribute to writing summaries and take part in the general Snowmass'21 events

Accelerator Frontier – Key Questions

1. What is needed to advance the physics?
2. What is currently available (state of the art) around the world?
3. What new accelerator facilities could be available on the next decade (or next next decade)?
4. What R&D would enable these future opportunities?
5. What are the time and cost scales of the R&D and associated test facilities as well as the time and cost scale of the facilities?

Accelerator Frontier: Topical Groups

- AF1: Beam Physics and Accelerator Education
- AF2: Accelerators for Neutrinos
- AF3: Accelerators for EW/Higgs
- AF4: Multi-TeV Colliders
- AF5: Accelerators for PBC and Rare Processes
- AF6: Advanced Accelerator Concepts
- AF7: Accelerator Technology R&D

Subgroup 1 :Magnets
Subgroup 2: RF
Subgroup 3: Sources and Targets

Accelerator Frontier Conveners

Topical Group		Topical Group co-Conveners			
AF1	Beam Phys & Accel. Education	Z. Huang (Stanford)	M. Bei (GSI)	S. Lund (MSU)	
AF2	Accelerators for Neutrinos	J. Galambos (ORNL)	B. Zwaska (FNAL)	G. Arduini (CERN)	
AF3	Accelerators for EW/Higgs	M. Ross (SLAC)	Q. Qin (IHEP, Beijing)	G.Hoffstaetter (Cornell)	
AF4	Multi-TeV Colliders	M. Palmer (BNL)	A. Valishev (FNAL)	N Pastrone (INFN, Torino)	J.Tang (IHEP, Beijing)
AF5	Accelerators for PBC and Rare Processes	E. Prebys (UC Davis)	M. Lamont (CERN)	R.Milner (MIT)	
AF6	Advanced Accelerator Concepts	C. Geddes (LBNL)	M. Hogan (SLAC)	P. Musumeci (UCLA)	R. Assmann (DESY)
AF7	Accelerator Technology R&D				
	Sub-group RF	E. Nanni (SLAC)	S. Belomestnykh (FNAL)	H. Weise (DESY)	
	Sub-Group Magnets	G. Sabbi (LBNL)	S. Zlobin (FNAL)	S. Izquierdo Bermudez (CERN)	
	Sub-Group Target/Sources	C. Barbier (ORNL)	Y. Sun (ANL)	F.Pellemoine (FNAL)	

9 out of 29 are representatives of Asia and Europe; 5 women

Accelerator Frontier: Liaisons

- AF to Theory Frontier - LianTao Wang (U Chicago)
- Rare Processes - Robert Bernstein (FNAL)
- Neutrino Frontier - Laura Fields (FNAL)
- Energy Frontier - Meenakshi Narain (Brown) and Dmitri Denisov (BNL)
- Instrumentation Frontier - Andy White (UTA)
- Computation Frontier - Jean-Luc Vay (LBNL)
- Community Engagement - Jeoren van Tilborg (LBNL)
- Snowmass Young - Edith Nissen (Jlab) and Nikita Kuklev (U.Chicago)

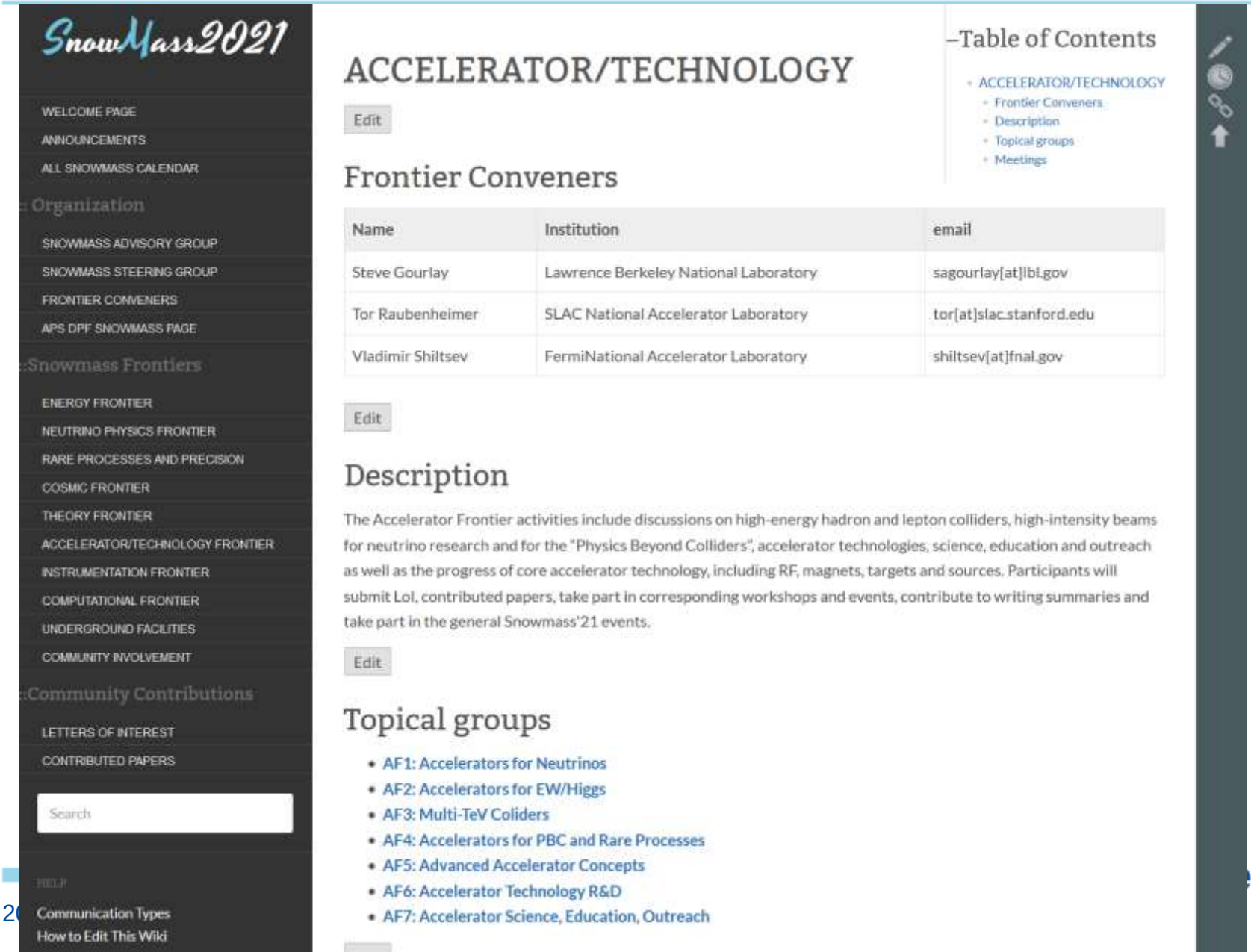
Joint Initial AF-EF Workshop on Future Colliders (16!)

June 24 and July 1 , 2020

Day 1: https://indico.fnal.gov/event/43871/

Day 2: https://indico.fnal.gov/event/43872/

https://snowmass21.org/accelerator/



SnowMass2021

WELCOME PAGE
ANNOUNCEMENTS
ALL SNOWMASS CALENDAR

Organization

SNOWMASS ADVISORY GROUP
SNOWMASS STEERING GROUP
FRONTIER CONVENERS
APS DPF SNOWMASS PAGE

Snowmass Frontiers

ENERGY FRONTIER
NEUTRINO PHYSICS FRONTIER
RARE PROCESSES AND PRECISION
COSMIC FRONTIER
THEORY FRONTIER
ACCELERATOR/TECHNOLOGY FRONTIER
INSTRUMENTATION FRONTIER
COMPUTATIONAL FRONTIER
UNDERGROUND FACILITIES
COMMUNITY INVOLVEMENT

Community Contributions

LETTERS OF INTEREST
CONTRIBUTED PAPERS

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ACCELERATOR/TECHNOLOGY

Edit

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- ACCELERATOR/TECHNOLOGY
  - Frontier Conveners
  - Description
  - Topical groups
  - Meetings

Frontier Conveners

Name	Institution	email
Steve Gourlay	Lawrence Berkeley National Laboratory	sagourlay[at]lbl.gov
Tor Raubenheimer	SLAC National Accelerator Laboratory	tor[at]slac.stanford.edu
Vladimir Shiltsev	FermiNational Accelerator Laboratory	shiltsev[at]fnal.gov

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Description

The Accelerator Frontier activities include discussions on high-energy hadron and lepton colliders, high-intensity beams for neutrino research and for the "Physics Beyond Colliders", accelerator technologies, science, education and outreach as well as the progress of core accelerator technology, including RF, magnets, targets and sources. Participants will submit LoI, contributed papers, take part in corresponding workshops and events, contribute to writing summaries and take part in the general Snowmass'21 events.

Edit

Topical groups

- AF1: Accelerators for Neutrinos
- AF2: Accelerators for EW/Higgs
- AF3: Multi-TeV Coliders
- AF4: Accelerators for PBC and Rare Processes
- AF5: Advanced Accelerator Concepts
- AF6: Accelerator Technology R&D
- AF7: Accelerator Science, Education, Outreach

329 AF LoIs (incl.71 joint - EF, NF, RPF, …)

- AF1: Beam Physics and Accelerator Education **61 (14)**
- AF2: Accelerators for Neutrinos **18 (5)**
- AF3: Accelerators for EW/Higgs **32 (4)**
- AF4: Multi-TeV Colliders **56 (10)**
- AF5: Accelerators for PBC and Rare Proc. **37 (22)**
- AF6: Advanced Accelerator Concepts **71 (5)**
- AF7: Accelerator Technology R&D **137 (6)**

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AF1: Beam Physics and Accel. Education

- **Main themes/directions of study:**
  - Physics of Multi-TeV colliders and ultimate beams (intensity, energy, brightness)
  - Fundamental beam physics (space-charge, plasma, beam cooling, electron lenses, ERL, instabilities, etc)
  - Modeling, AI and Machine Learning
  - Education, Outreach, Diversity - centers/programs for general research/training
  - Sustainability and energy management of accelerators
- **Future events/meetings/workshops:**
  - **#1: On Education, Diversity and Outreach - ~2021**
  - **#2: Research Centers/Facilities - TBD**
    - Joint with AF4, AF6: discuss needs of test/R&D facilities to support accelerator R&D, training, and educational needs.
  - **#3: Computational Tools & Machine Learning - TBD**
    - joint with Computational Frontier to cover tools extending modeling capabilities, potential ML impacts, more efficient use of resources.
  - **#4: Physics Limits of Ultimate Beams – Q1-Q2 2021**
    - joint with AF4, AF6, and ARIES to discuss ultimate beam parameters such as energy, intensity, brilliance, beam power on-target allowed by the fundamental laws of physics. Discuss practical limits from engineering and technology.

AF2: Accelerators for Neutrinos

- **Main Themes:**
  - Existing Facilities
  - Planned Upgrades
  - Proposed New Facilities/Upgrades
  - Test Facilities
  - Enabling R&D / Technology

Taking as input the anticipated needs of particle physics and the requirements for neutrino beams in terms of energy, flux, temporal and spatial characteristics, this group will discuss:

- The **proton** (or other) **beam requirements** to meet the **neutrino physics** community needs
- The **capability** of existing or planned accelerator facilities to satisfy the above requirements, and If not: the necessary upgrades or new facilities.
- **Enabling R&D**, technologies, and test facilities necessary to develop upgrades and new facilities.

- **Meetings:**
  1. AF2 Town Hall - Nov 12, 9am-noon
  2. Solicited community workshops - TBD
  3. Joint workshops under consideration - TBC
     - with AF5(rare processes) on joint use of facilities
     - with AF7t (targets for neutrino facilities)
     - with NF09 (artificial neutrino sources)
  4. Plenary AF2 Workshop - April 27-28, 2021 (TBC)

AF2 Wiki page: https://snowmass21.org/accelerator/neutrino/start

List for AF2 announcements: snowmass-af2-accel-for-nu@listserv.fnal.gov

AF3: Colliders for Electro-Weak/Higgs

- Overview of 8 Higgs Factories schemes

- **Main themes:**
  - R&D needs for FCCee, CepC, ILC, and ERL-FCCee
  - upgrade sequencing to the high-energy frontier, inc. *pp* col.
  - upgrades to the ILC, e.g. by plasma acceleration
  - Technology push:
    - SRF and magnet tech for ring and linac Higgs factories
    - Potential technology improvements, esp. SRF
    - Progress toward superconducting undulator for pol. *e+*

- **Future events:**
  - Meetings on: *i) accelerator physics issues, ii) on key technologies, iii) on power consumption, and iv) on upgrade schemes.*
  - Dates TBD… joint with other AF and EF groups
  - Provide input for the AF ITF (Implementation Task Force)

AF4: Multi-TeV Colliders

- **Key Topics:**

  AF4 is closely coupled with EF/TF (possibly IF). Key deliverable will be the summary of collider facility options. Initially grouped by species ***ee, pp, ep/i, μμ, γγ…*** for each:

  - Physics reach, Parameters, Technology challenges, Maturity

- **Actions/meetings between CPM and CSS:**
  - Two Meetings, Joint with **EF**/TF/IF:
    1. Q1-Q2 2021. Main discussion – **physics reach / potential** for multi-TeV machines. Summarize for EF parameters /challenges /maturity. Make formal request to established collaborations for White Papers.
    2. 2021. 2nd iteration based on new information. Added topics: **staging options,** revisit **R&D requirements**. Review draft White Papers.
  - Meeting - Joint with AF1: Revisit fundamental challenges and thinking paradigms. Discuss 'return on investment' and novel approaches. - TBD
  - Meetings on Technology challenges - TBD
    - On MDI ½-day in January across AF/IF.
    - Participate in AF7-Technology topical groups events.
  - Provide input to the ITF once the process is well underway. Our work is closely related, need to agree how to proceed.

Can provide preliminary summary after 2021 Joint meeting with EF.

AF5: Accelerators for Rare and BCP

- Main themes:
  - Beam dump opportunities (*p* and *e*)
  - Non-collider axion/dark sector synergy with HEP magnet, RF, and quantum sensor R&D
  - Dedicated rings for EDM measurement
  - Beam delivery from PIP-II (incl. compressor ring)
  - Potential for laser wakefield driven experiments
- Future events:
  - Facilities workshop: AF5 and guests
    - Accelerator and other support (RF, Magnets, etc) available or potentially available at labs.
  - At least one more joint meeting with RPF subgroups
  - The idea of a small joint beam dump/ν-target workshop to discuss targetry needs came up – joint with AF2
  - Coordinate with “Beyond PIP-II” group.
  - Dates: TBD

AF6: Advanced Accelerator Concepts

Recent : AF6 Workshop September 23-24, 2020 to prepare for CPM:

- Chance for all LOI's 'to be heard' - two-full days with over 50 LOIs!
https://indico.fnal.gov/event/45651/

AF5 is organized around **common themes** that are suggesting possibilities for a much smaller number of collaborative, focused *Contributed Papers* (to be confirmed):

- i) Collider concepts, ii) wakefield acceleration, iii) particle sources, iv) test facilities, v) interaction point, vi) near term applications, vii) alternate schemes

Looking ahead:

- Once a month: Interest groups are being formed to maintain momentum heading to June 2021 and afterwards – so far Joint AF6-Computation (Jean-Luc Vay), Advanced Accelerator Concepts (Eric Esarey), Test Facilities (Vitaly Yakimenko)
- Once a week: Re-branded AAC Seminar Series this winter will be a forum for continued community engagement with weekly meetings beginning Nov. 16th (http://aac2020.lbl.gov)
- Additional AF6 workshops will be organized after cross frontier CPM input is digested

To stay up to date on AF6 planning/workshops please subscribe to the mailing list:

- To sign up, send an email to listserv@fnal.gov with a blank subject and with the body of the message consisting of the text: SUBSCRIBE SNOWMASS-AF-06-AAC firstname lastname

AF7m: Accelerator Technology - Magnets

Two main categories

- Magnets for various machines:
  - high field and low field accelerator magnets for hadron colliders
  - fast cycling magnets and solenoids for muon colliders
  - solenoids for detectors
  - undulators for γγ and linear colliders
  - beam lines
- General accelerator magnet R&D:
  - SC wires and cable
  - magnet design (HTS, LTS, Hybrid, Fast Cycling HTS magnets)
  - diagnostics, test facilities and cryogenics
  - magnet R&D programs in the U.S., EU, Japan and China

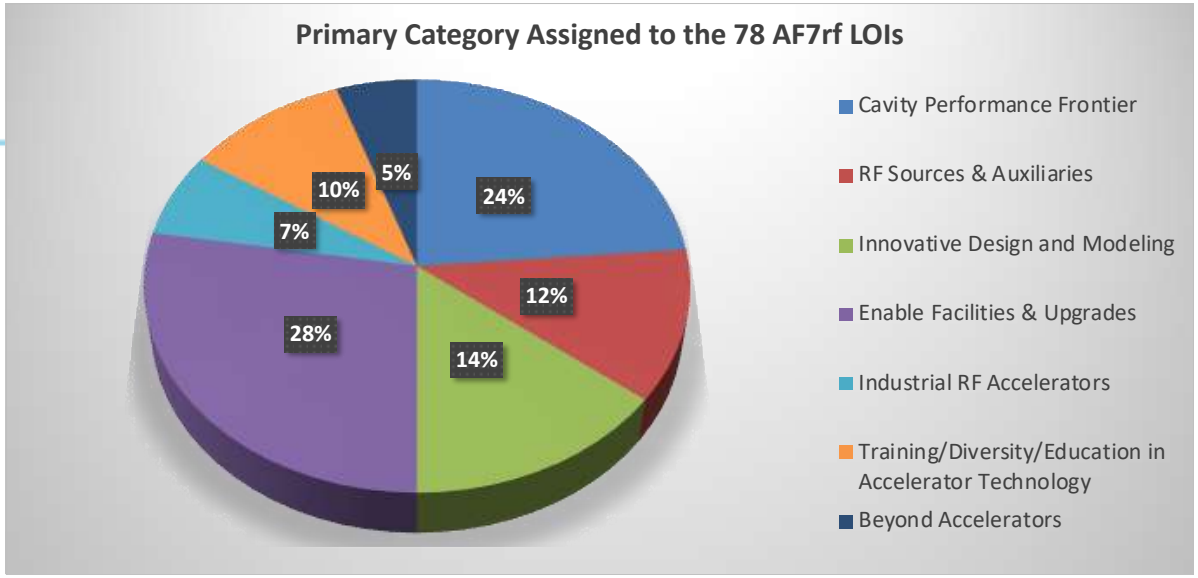
Excellent representation of various magnets from the 3 regions (US, EU, Asia)!

- Two working groups will be formed (leads TBD)
  - Magnets for various machines (AFs)
  - General accelerator magnet designs, technologies, performance, cost optimization

- **Work organization:**
  - AF7-Magnets joint group meeting(s) to develop key questions and opportunities – by January 2021
  - AF7-Magnets virtual workshop and joint meetings/workshops with AF1-6 to produce preliminary report and WP drafts – by April 2021
  - AF7-Magnets virtual group meeting to coordinate various contributions to the report and WP status – by June 2021

AF7rf: RF

- **Categorized into 7 different categories** (see pie chart on the right)



- **Plans include :**
  - Workshop on "Cavity Performance Frontier" - TBD
  - Workshop on "RF Sources & Auxiliaries" – TBD
  - Workshop on "Innovative Design and Modelling" – TBD
  - Joint workshops with other groups for other four categories, or have smaller mini-workshops
  - Online **survey** conducted during & after AF7rf session on Tuesday shows good agreement on proposed path forward
  - Also plan to continue seminar series – see previous seminars at indico.fnal.gov/category/1117/

SNOWMASS-AF7-TS@LISTSERV.FNAL.GOV

- **Main topics – Targets:**
  - Material Studies to Extend Radiological Material Science
    - Radiation damage in material
    - Post Irradiation Examination (PIE)
    - Irradiation station
  - Improved Modelling
    - Capturing more physics, Better prediction of target lifespan, Code integration, Leverage AI to optimize target design
  - Novel Materials and Novel Concepts
  - Rad-Hard Instrumentation
    - Device monitoring
  - Remote Handling and Operations (leverage AI)
  - Specialized "Physics" targets
    - For individual experiments

- **Events – Targets:**
  - Town Hall Meeting with AF liaisons
  - Satellite workshops:
    - High Power Targetry Workshop (RIKEN, May 21)
    - RaDIATE annual collaboration meeting (BNL, Spring 21)
  - Workshop on Modeling and instrumentation (Date TBD)

AF7ts: Targets/Sources

- **Main topics – Sources:**
  - High Brightness / High Average Current Electron Sources:
    - Cathodes
    - Guns
    - Injectors
  - High Intensity Ion Sources
    - Intensity
    - Charge state
  - High Intensity Positron/Proton/Muon Sources
    - Polarization;
    - High intensity (orders of magnitude higher than existing positron sources)

- **Events – Sources:**

Three workshops with invited talks; dates TBD.

1. **Workshop on High Brightness / High Average Current Electron Sources (C. Hernandez-Garcia, S. Karkare)**
   - –Cathodes
   - –Guns
   - –Injectors
2. **Workshop on High Intensity Ion Sources (D. Xie)**
   - –Electron Cyclotron Resonance Ion Sources(ECRISs)
   - –Electron Beam Ion Source (EBIS)
3. **Workshop on High Intensity Positron/Proton/Muon Sources/H^- (M. Biagini)**
   - –Positron sources for e+e-/ μ+μ- collider projects (ILC, CLIC, SuperKEKB, FCC-ee, LEMMA, etc.)
   - –Photons→Protons
   - –Positron→ Muons (e.g. LEMMA)
   - –Protons→Muon (MAP Muon source for MCC)
   - –H^-

Snowmass'2021 : Accelerator Frontier

– Implementation Task Force

AF Implementation Task Force

- Key question for Snowmass'21 Accelerator Frontier to address: *"…What are the time and cost scales of the R&D and associated test facilities as well as the time and cost scale of the facility?"*
- A large number of possible accelerator projects: ILC, Muon Collider, gamma-gamma and ERL options, a large circumference electron ring, and a large circumference hadron ring amongst others.
- Comparison of the expected costs (using different accounting rules), schedule, and R&D status for the projects.
- The *Accelerator Implementation Task Force* comprises of 9 world-renowned accelerator experts from Asia, Europe and US and two reps. of the *Snowmass Young*; it is chaired by Thomas Roser (BNL) and charged with developing metrics and processes to facilitate a comparison between projects (see next slide).


Thomas Roser (BNL, Chair)


Philippe Lebrun (CERN)


Steve Gourlay (LBNL)


Tor Raubenheimer (SLAC)


Katsunobu Oide (KEK)


Jim Strait (FNAL)


Marlene Turner (LBNL)


Spencer Gessner (SLAC)


Vladimir Shiltsev (FNAL)


Reinhard Brinkmann (DESY)


John Seeman (SLAC)

Implementation Task Force: Charge

1. Develop the metrics to compare projects' cost, schedule/timeline, technical risks (readiness), operating cost and environmental impact, and R&D status and plans;
2. Select the accelerator projects to be evaluated (provided by the AF topical groups);
3. Work with the proponents of the selected accelerator projects to evaluate them against the metrics from item 1;
4. Consider the ultimate limits of various types of colliders: e+/e-, p/p, mu+/mu-;
5. Consider limits and timescales due to accelerator technology for various types of colliders: e+/e-, p/p, mu+/mu-;
6. Lead the evaluation of the different HEP accelerator proposals and inform and communicate with the Snowmass'21 AF, EF, NF and TF;
7. Document the metrics, processes, and conclusions for the *Snowmass'21* meeting in the Summer 2022; write and submit a corresponding White Paper.

Implementation Task Force: Status

- ITF is focusing on collider facilities.
- AF topical groups (AF3,4,6) have provided initial lists of proposals and concepts for evaluation to the ITF (see next slides).
- Proposal for four categories:
  1. Existing facilities for references (Tevatron, RHIC, LEP, LHC, Super KEKB, XFEL, LCLS II ...) **[Existing]**
  2. Proposals with TDR and/or CDR **[CDR/TDR]**
  3. Proposal without TDR or CDR but reasonably well thought through and mostly based on existing technologies. An estimate for component counts exists. **[Concept]**
  4. Future concepts and ideas **[Future concepts]**
- The ITF has developed a set of metrics that will be used to evaluate the proposals and concepts. A spreadsheet to be filled out by the proponents of proposals and concepts will be distributed soon.
- ITF will assemble and evaluate all this information and prepare an overall comparison of all the proposals and concepts. This will be presented to the AF topical groups at a workshop (mid-2021?), for comments and feedback.
- ITF will prepare a White Paper with the metrics, processes and conclusions for Snowmass'21 in Q1 2022.

ITF: Higgs Factory Concepts/Proposals (8)

Name	Details	POC	AF Group
CepC	e+e-, $\sqrt{s} = 0.24$ TeV, L= 3.0×10^{34}	Jie Gao (gaoj@ihep.ac.cn)	AF3
CLIC (Higgs factory)	e+e-, $\sqrt{s} = 0.38$ TeV, L= 1.5×10^{34}	Steinar Stapnes (Steinar.Stapnes@cern.ch)	AF3
ERL ee collider	e+e-, $\sqrt{s} = 0.24$ TeV, L= 73×10^{34}	Thomas Roser (roser@bnl.gov)	AF3
FCC-ee	e+e-, $\sqrt{s} = 0.24$ TeV, L= 17×10^{34}	Katsunobu Oide (katsunobu.oide@ern.ch)	AF3
gamma gamma	X-ray FEL-based $\gamma\gamma$ collider	Tim Barklow (timb@slac.stanford.edu)	AF3
ILC (Higgs factory)	e+e-, $\sqrt{s} = 0.25$ TeV, L= 1.4×10^{34}	Shin-ichi Michizono (shinichiro.michizono@kek.jp	AF3
LHeC	ep, $\sqrt{s} = 1.3$ TeV, L= 0.1×10^{34}	Oliver Bruening (oliver.bruening@cern.ch)	AF3
MC (Higgs factory)	$\mu\mu$, $\sqrt{s} = 0.13$ TeV, L= 0.01×10^{34}	Mark Palmer (mpalmer@bnl.gov)	AF3

… and 18 (!) high energy collider concepts/proposals (see next slide)

ITF :18 (!) high energy collider concepts/proposals

Name	Details	POC	AF Group
Cryo-Cooled Copper linac	e+e-, $\sqrt{s} = 2$ TeV, L= 4.5×10^{34}	Emilio Nanni (nanni@slac.Stanford.edu)	AF3
High Energy CLIC	e+e-, $\sqrt{s} = 1.5 - 3$ TeV, L= 5.9×10^{34}	S.Stapnes (steinar.stapnes@cern.ch)	AF4
High Energy ILC	e+e-, $\sqrt{s} = 1 - 3$ TeV	Hassan Padamsee (hsp3@cornell.edu)	AF4
FCC-hh	pp, $\sqrt{s} = 100$ TeV, L= 30×10^{34}	M.Benedikt (Michael.Benedikt@cern.ch)	AF4
SPPC	pp, $\sqrt{s} = 75/150$ TeV, L= 10×10^{34}	J.Tang (tangjy@ihep.ac.cn)	AF4
Collider-in-Sea	pp, $\sqrt{s} = 500$ TeV, L= 50×10^{34}	P.McIntyre mcintyre@physics.tamu.edu	AF4
LHeC	ep, $\sqrt{s} = 1.3$ TeV, L= 1×10^{34}	Y.Zhang (yzhang@jlab.org)	AF4
FCC-eh	ep, $\sqrt{s} = 3.5$ TeV, L= 1×10^{34}	Y.Zhang (yzhang@jlab.org)	AF4
CEPC-SPPpC-eh	ep, $\sqrt{s} = 6$ TeV, L= 4.5×10^{33}	Y.Zhang (yzhang@jlab.org)	AF4
VHE-ep	ep, $\sqrt{s} = 9$ TeV	Y.Zhang (yzhang@jlab.org)	AF4
MC – Proton Driver 1	$\mu\mu$, $\sqrt{s} = 1.5$ TeV, L= 1×10^{34}	D.Schulte (daniel.schulte@cern.ch)	AF4
MC – Proton Driver 2	$\mu\mu$, $\sqrt{s} = 3$ TeV, L= 2×10^{34}	D.Schulte (daniel.schulte@cern.ch)	AF4
MC – Proton Driver 3	$\mu\mu$, $\sqrt{s} = 10 - 14$ TeV, L= 20×10^{34}	D.Schulte (daniel.schulte@cern.ch)	AF4
MC – Positron Driver	$\mu\mu$, $\sqrt{s} = 10 - 14$ TeV, L= 20×10^{34}	D.Schulte (daniel.schulte@cern.ch)	AF4
LWFA-LC (e+e- and $\gamma\gamma$)	Laser driven; e+e-, $\sqrt{s} = 1 - 30$ TeV	Carl Schroeder (CBSchroeder@lbl.gov)	AF6
PWFA-LC (e+e- and $\gamma\gamma$)	Beam driven; e+e-, $\sqrt{s} = 1 - 30$ TeV	Gessner, Spencer J. (sgess@slac.edu)	AF6
SWFA-LC	Structure wakefields; e+e-, $\sqrt{s} = 1 - 30$ TeV	Chunguang Jing (jingchg@anl.gov)	AF6

ITF: Set of Metrics for Colliders (1)

1. Physics Reach (8):
    1. Parton collision energy range
    2. Parton luminosity
    3. Parton CM energy spread at collisions
    4. Length between IP and final focussing quad
    5. Minimum IP detector radius
    6. Time between collisions
    7. Pile up
    8. Number of collision points
2. Beam parameters (7):
    1. Nominal beam energy
    2. Design luminosity at nominal beam energy
    3. Range of operational beam energy
    4. Stored Energy (per beam)
    5. Beam power (per beam) at collision energy
    6. Total lost power for both beams
    7. IP Beam sizes

ITF: Set of Metrics for Colliders (2)

3. Size and Complexity of Facility (8):

1. Length of all accelerators
2. Length of new accelerators
3. Length of all tunnels
4. Length of new tunnels
5. Length of special insertions (final focus, collimation, ...)
6. Number of new magnets
7. Number of new acceleration cavities
8. Total length of new vacuum chambers

4. Technical risk (5+):

1. Key technologies that require R&D
2. For each key technology fill in the three rows below:
    1. Technology Readiness Level (TRL)
    2. Maturity of proposal/concept
    3. Validation: demonstration projects required, …
3. Alignement tolerance
4. Vibration tolerance
5. Tuning stability

ITF: Set of Metrics for Colliders (3)

5. Schedule (6):

1. Study and R&D to CDR (pre CD-1)
2. Design, industrialization, and TDR (post CD-1)
3. Civil Construction, fabrication. and Installation (post CD-3)
4. Commissioning
5. Operation to first physics results
6. Operation to full physics goals

6. Validation and Preparation (4):

1. Scope of demonstration projects
2. size of demonstration projects
3. Estimated total cost of demonstration projects
4. Industrialization, planning (pre-CD2: R&D and design)

ITF: Set of Metrics for Colliders (4)

7. Construction Cost (7):

1. Accelerator systems
2. Accelerator infrastructure
3. Civil engineering
4. Personnel
5. Estimated uncertainty
6. including personnel, electric energy, M&S - get KPPs
7. Decommissioning cost (if known)

8. Operation and Maintenence (5):

1. Electrical power consumption
2. Annual electrical energy consumption
3. Energy management
4. Maintenance & spares
5. Personnel

ITF: Set of Metrics for Colliders (5)

9. Environmental Impact (4):
    1. Land use
    2. Radiation risk (low-medium-high)
    3. Effluents
    4. Carbon footprint reductions
    5. Heat rejection & disposal
10. Economic/technological impact (if known)
11. Cultural/educational impact (if known)

Snowmass'2021 : Accelerator Frontier

- Muon Collider Forum
  - Joint EF-AF-TF-IF Initiative
  - Aspirations for energy frontier facility in the US
  - Based on results of successful US-MAP (ended in 2016) and bold CERN-led initiative in Europe

Steps Toward Muon Collider : Europe

EU Strategy → International Design Study

European Strategy Update – June 19, 2020:

3 ! High-priority future initiatives

High-priority future initiatives [..]In addition to the high field magnets the **accelerator R&D roadmap** could contain:
[..] an **international design study** for a **muon collider**, as it represents a unique opportunity to achieve a *multi-TeV energy domain beyond the reach of e^+e^-colliders*, and potentially within a *more compact circular tunnel* than for a hadron collider. The biggest challenge remains to produce an intense beam of cooled muons, but *novel ideas are being explored*;

European Large National Laboratories Directors Group (LDG) – July 2

LDG chaired by Lenny Rivkin

Agree to start building the collaboration for international muon collider design study

Accept the proposal of organisation

Accept the goals for the first phase

Daniel Schulte ad interim project leader

Strengthening cooperation and ensuring effective use complementary capabilities

Core team: N. Pastrone, L. Rivkin, D.Schulte

International Muon Collider Collaboration kick-off virtual meeting - July 3

(>250 participants) https://indico.cern.ch/event/930508/

High Energy $\mu^+\mu^-$ Colliders

***Advantages*:**

- ***μ***'s do not radiate when bent → acceleration in rings →

smaller footprint

low cost

great power efficiency

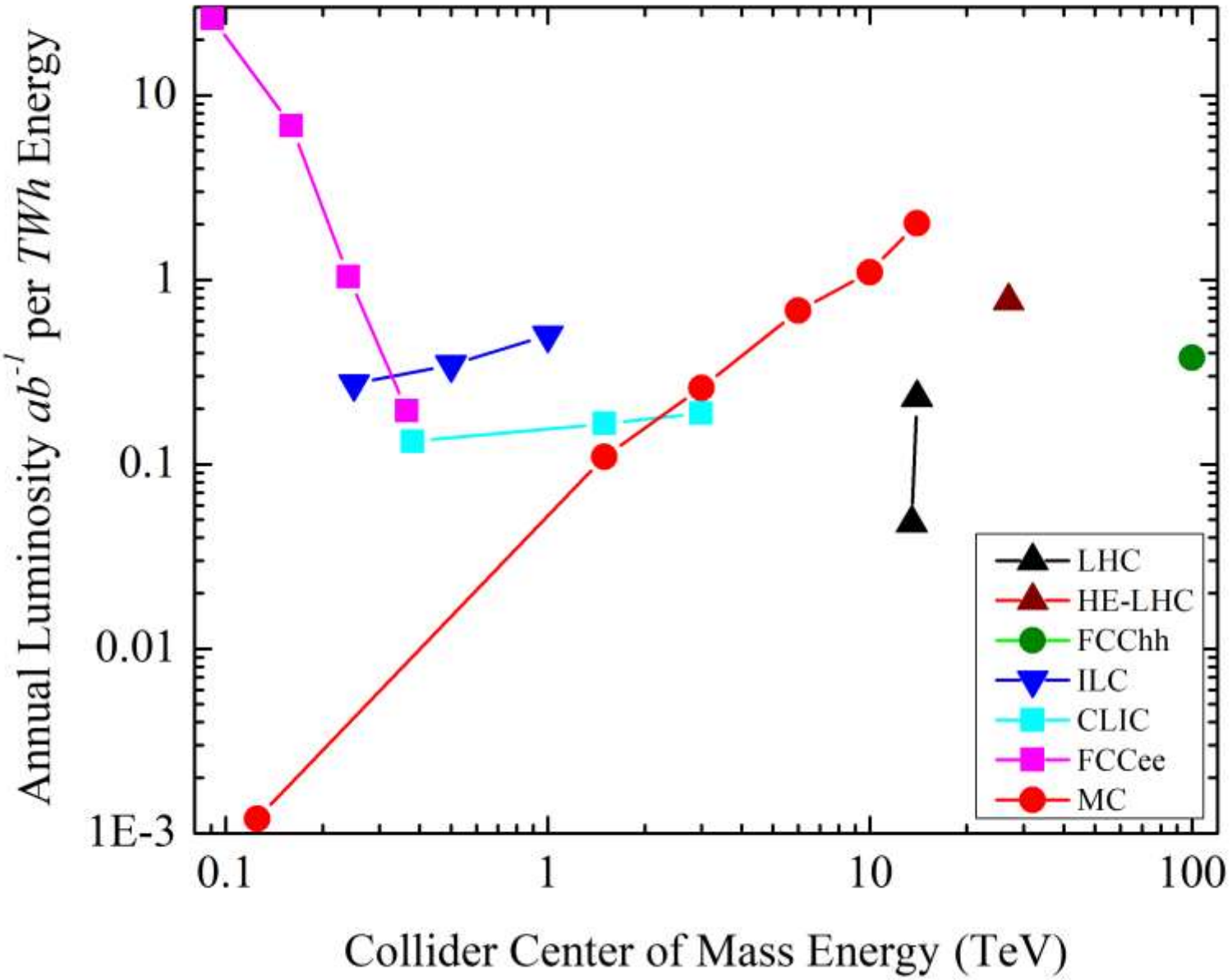
- ~ x*7* energy reach vs *pp*

Offer *"moderately conservative - moderately innovative"* path **to cost affordable** energy frontier colliders:

Power efficiency

arXiv:2003.09084

to appear in Nature Physics



Muon Collider Forum (next week)

Muon Collider Forum Kickoff meeting

Wednesday Jan 27, 2021, 10:30 AM → 12:30 PM US/Central

https://indico.fnal.gov/event/47038/

Description Topic: Muon Collider Forum Kickoff

Time: Jan 27, 2021 10:30 AM Central Time (US and Canada)

10:00 AM → 10:10 AM **Introduction**

10:10 AM → 10:30 AM **Muon Collider summary from TF**
Speakers: Fabio Maltoni (Universite' catholique de Louvain), Patrick Meade (Stony Brook University)

10:30 AM → 10:50 AM **Muon Collider summary from AF**
Speakers: Derun Li (LBNL), Diktys Stratakis (Fermi National Accelerator Laboratory)

10:50 AM → 11:10 AM **Muon Collider summary from EF**
Speakers: Kevin Black, Sergo Jindariani (FNAL)

11:10 AM → 12:10 PM **Discussion**

Snowmass'2021 : Accelerator Frontier

–Physics Limits of Ultimate Beams

As part of the Snowmass2021 community discussion, AF1 (Accelerator Science, Education, Outreach), AF4 (Multi-TeV Colliders) and AF6 (Advanced Accelerator Concepts) launch a joint workshop on the topic of Physics limits of Ultimate beams. The main scope of this workshop is to engage the community to explore:

- Fundamental ultimate beams for various physics goals. In particular, for colliders, we would like to understand the required luminosity scaling with energy
- Potential and feasibility of advanced concepts towards the ultimate physics limits, such as PeV beams yet low luminosity etc.

Physics Limits of Ultimate Beams

The first two sessions :

Dec 3, 2020: Discovery Physics of electron-electron, gamma-gamma colliders - Michael Peskin (SLAC)
Physics Potentials with Low Luminosity Super High Energy Colliders - Allen Caldwell (Munchen)

https://indico.fnal.gov/event/46645/

Dec 18, 2020: Wishes from Acc Implementation task force: required inputs for your task - Thomas Roser (BNL)
Desired ultimate beams for probing BSM physics at colliders: scale of required lumi. vs. energy - Liantao Wang (University of Chicago)

https://indico.fnal.gov/event/46742/

Physics Limits of Ultimate Beams -III (tomorrow)

Physics Limits of Ultimate Beams

Friday Jan 22, 2021, 3:00 PM → 5:00 PM US/Central

https://msu.zoom.us/j/95924457368

Carl Schroeder (Lawrence Berkeley National Laboratory), Frank Zimmermann (CERN), Mark Palmer (Brookhaven National Laboratory), Mei Bai (GSI), Pietro Musumeci (UCLA), Steven Lund (USPAS / MSU / FRIB), Zhirong Huang (SLAC National Accelerator Laboratory)

3:00 PM → 3:45 PM **Ultimate Beams and Physics/Accelerator Technologies Beyond Colliders**
Speaker: Swapan Chattopadhyay (Fermilab/NIU)

3:45 PM → 4:30 PM **Overview of the achieved collider performance and scaling rules**
Speaker: Vladimir Shiltsev (FNAL)

4:30 PM → 5:00 PM **Discussions**

https://indico.fnal.gov/event/47217/

Fermilab

Snowmass'21 Accelerator Frontier: Summary

- It has been difficult times
  - Impact of COVID-19 on particle physics and accelerator research
  - All of the Snowmass meetings and workshops so far have been virtual.
  - We have challenges to deal with uncertainty in 2021-22.
- In spite of this, there have been tremendous efforts and major progress by the community:
  - *Huge thanks to the AF community, Topical Groups' and ITF leaders!!*
- Snowmass is a community-driven process:
  - We appreciate the community's continued strong participation in the process
  - We very much welcome the international accelerator community - **please, join us!!**
  - Visit the Snowmass AF wiki page (https://www.snowmass21.org/accelerator/) to find out the best place to contribute
- We very much look forward to a productive Snowmass study