Overview of the preparation for the Snowmass process at the laboratory

Frank Chlebana (for the SAC)
Nov 18, 2021

Charge

… comment on the effectiveness of the **internal organization**, on the **participation of the laboratory's scientists** in the re-start of the process, and on the **role the laboratory** may play.

Overview

Organization / past meetings

Summary from Community Planning Meeting

Integration of effort into snowmass organization

Summary / status from All-Scientist retreat 2021

- List of topics for white papers

Role of SAC Scientific Working Groups

- Snowmass, post snowmass -> P5, internal planning (IPPM)

Discussion on the organization and post Snowmass planning

SAC Scientific Working Groups

SAC Scientific Working groups established in 2019 prior to the All-Scientist Retreat

Retreat focused on: Assessing the Scientific Interest Level / Resource Identification

Overall goal was to ensure Fermilab is ready to contribute to Snowmass community planning effort!

- **Precision Frontier**: precision-science@fnal.gov
  Conveners: Chris Polly, Ron Ray
- **Energy Frontier**: fermilab_ef@fnal.gov, future-colliders-fermilab@fnal.gov
  Conveners: Pushpa Bhat, Anadi Canepa, Paddy Fox, Sergo Jindariani, Sergei Nagaitsev
- **Cosmic Frontier**: fcpa_general@fnal.gov
  Conveners: Brad Benson, Gordan Krnjaic, Albert Stebbins, Alex Drlica-Wagner
- **Neutrino Frontier**: sac_neutrinos@fnal.gov
  Conveners: Minerba Betancourt, Zarko Pavlovic, Joseph Zennamo, Peter Shanahan
- **Detector Frontier**: detectors@fnal.gov
  Conveners: Juan Estrada, Angela Fava, Zoltan Gecse, Vadim Rusu
- **Quantum Frontier**:
  Conveners: TBD, TBD
- **Accelerator Frontier**: contact conveners
  Conveners: Maria Baldini, Mattia Checchin, Frederique Pellemoine, Arun Saini, Vladimir Shiltsev
- **Computing Frontier**: sac-comp-wg@fnal.gov
  Conveners: Kyle Knoepfel, Adam Lyon

Good alignment with the Snowmass Frontiers.

Some convenors are not available to continue after the "pause".

Names in red also hold roles within Snowmass Organization (see backup slides)

Community Planning Meeting

The SAC helped organize the Snowmass Community Planning Meeting (Oct 5-8, 2020)

- Comprehensive look at interests across the community via LOIs
- Some frontier groups recognized new/increased interest in certain topics
  - Additional liaisons across frontiers and workshops around such topics are being organized
- Broad discussion of how to get to an organized and structured message going to the CSS
- Planning of activity in the months leading up to the CSS
  - E.g., Some LOIs have been identified to join into single white papers
- CPM was a major step towards the 2022 Snowmass CSS
- >3k participants from around the world
  - *Largest Snowmass-related event so far*

Fermilab scientists was essential to the meeting's success

In organization, convening, scientific contribution, and meeting participation

Organization and Meetings Timeline

- Creation of the SAC Scientific Working Groups (2019)
- All-Scientist Retreat 2019 (June 14, 2019)
- Dedicated All-Scientist meeting focusing on Snowmass LOI Planning (Aug 21, 2020)
- *Effort has been integrated into the Snowmass organization*
- Snowmass Community Planning Meeting (Oct 5-8, 2020)

PAUSE

- All-Scientist Quarterly meetings with Snowmass focus (Dec 4, 2020, Apr 2, 2021, Aug 4, 2021) https://indico.fnal.gov/category/905/
- All-Scientist Retreat 2021 (Sep 9-10, 2021)

RESUME

- Snowmass Day (Sept 24, 2021)
- *All-Scientist Quarterly Meeting (Dec 3, 2021)*

Goal of the All-Scientist Retreat

Make sure the interests of the lab scientists are included in the snowmass report (white papers)

Discuss post-snowmass strategy (P5)

All-Scientist Retreat 2021

The SAC organized a two day retreat

Day 1: Focus on social issues and lab policy

Day 2: Focus on the scientific program

The 2021 All-Scientist retreat **builds on the work done in previous retreats** with the goal to identify future projects that Fermilab's scientists are most interested in pursuing, are aligned with the community interests, and to *develop a strategy for having them included in the P5 report*. The retreat also aims to facilitate the resumption of the Snowmass process and to encourage broad participation.

Report from the 2019 retreat:

https://fermipoint.fnal.gov/org/ood/sac/Shared%20Documents/2019%20Files/Summary_of_2019_All_Scientist_Retreat.pdf

Working group summaries/discussion in following all-scientist quarterly meetings *(first one planned for Dec 3)*

Precision WG Retreat Summary

High level of interest

- Mu2e-II
- LDMX, DarkQuest, M^3 - fixed target and beam dump searches

Medium level of interest

- ENIGMA - CLFV program at PIP-II
- REDTOP - eta factory
- PIONEER - lepton universality and precision tests with pions

Low level of interest

- Storage ring EDMs (proton/muon)

LOIs submitted for all topics listed above.
White papers under development for all of them (some with more or less Fermilab participation).

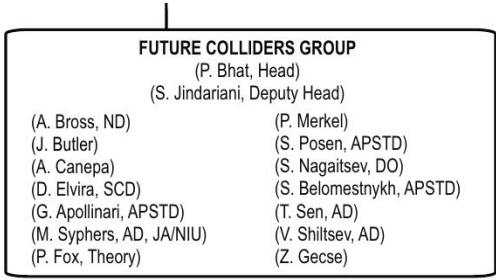
Energy WG Retreat Summary

Creation of the new Future Colliders Group

(1) Develop and facilitate Fermilab's engagement in future collider projects across accelerators, technology, particle physics and detectors, (2) to provide a forum to synergize efforts on future accelerators/colliders across frontiers, and (3) to develop a roadmap for further design studies and R&D for future colliders.

The members of the FCG include the co-conveners of the SAC Energy Frontier working group, representatives from divisions across the Lab, liaisons to the Integrated Planning and Performance Management and the detector R&D group.

Extractacted from FNAL Org chart



- ILC effort in Japan, particularly on SRF R&D and with various working groups of the ILC International Development Team
- FCC -ee/hh feasibility studies at CERN, related technology R&D as well as physics and detector studies,
- International Muon Collider Collaboration (MCC) that was launched this year, hosted by CERN, in which many US scientists are participating.
- Fermilab hosted future colliders (Site Filler)

Synergies with other Detector and Computing frontiers: *Advancements of the detector technologies, specifically development of 4D trackers, Particle-Flow Calorimetry, novel reconstruction strategies.*

Approximately 10 Energy Frontier **LOIs dedicated to physics studies** have been submitted to Snowmass with Fermilab scientists serving as primary contacts.

Planned white papers: - Future Collider in the US, Dijets at pp colliders, Muon Collider Physics, pMSSM scans for future colliders, 2 papers on HH: resonant and non-resonant, Studies of VBS. Well aligned with our interests in future physics and instrumentation

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Cosmic WG Retreat Summary (1/2)

Cosmic Microwave Background

CMB-S4 was endorsed by the 2014 P5 report, to be funded in any funding scenario, and in July 2019 the project achieved CD-0 status.

Dark Matter Direct Detection

Axion Dark Matter: Fermilab seeks to be the center of the world's axion program in the 2030's.

Sub-GEV Dark Matter: OSCURA Skipper CCD experiment and SuperCDMS.

Coordination with photon detector development

Dark Matter Cosmic Surveys

A Stage V dark energy spectroscopic survey (broadly defined) is the highest priority experiment for the cosmic surveys group on the 2030 timescale.

Cosmic WG Retreat Summary (2/2)

Cosmic frontier White Papers covering Fermilab related topics

White Paper Submission Database

Overall EF NF RPF CF TF AF IF CompF UF CommF Complementarity Reports

The landscape of cosmic-ray and high-energy-photon probes of particle dark matter	N	Y	CF01	Particle-like Dark Matter
Puzzling excesses and how we can resolve their origin/existence	N	Y	CF01	Particle-like Dark Matter
Synergies between DM searches and multiwavelength/multimessenger astrophysics / understanding astrophysical backgrounds	N	Y	CF01	Particle-like Dark Matter
Ultraheavy particle dark matter / probing the heaviest particle dark matter candidates	N	Y	CF01	Particle-like Dark Matter
Prediction for the Axion mass and consequences for cosmology and direct detection (Theory)— Pre-Inflation	N	Y	CF02	Wave-like Dark Matter
Prediction for the Axion mass and consequences for cosmology and direct detection (Theory)— Post-Inflation	N	Y	CF02	Wave-like Dark Matter
Beyond the Axion and ALPs— Scalars, Vectors, etc.	N	Y	CF02	Wave-like Dark Matter
Astrophysics and Wavelike Dark Matter	N	Y	CF02	Wave-like Dark Matter
Towards the QCD coupling with photons (Experimental): < 1 μeV	N	Y	CF02	Wave-like Dark Matter
Towards the QCD coupling with photons (Experimental): 1 μeV–1 meV	N	Y	CF02	Wave-like Dark Matter
Towards the QCD coupling with photons (Experimental): > 1 meV	N	Y	CF02	Wave-like Dark Matter
Novel Ideas for Wavelike Dark Matter (Atomic, Accelerometers, NMR, and Interferometry)— Part 1	N	Y	CF02	Wave-like Dark Matter
Novel Ideas for Wavelike Dark Matter (Atomic, Accelerometers, NMR, and Interferometry)— Part 2	N	Y	CF02	Wave-like Dark Matter
Quantum Technologies and Novel Materials for Wave-Like Dark Matter— the "back-end readout or sensor"	N	Y	CF02	Wave-like Dark Matter
Dark matter physics from halo measurements	N	Y	CF03	Dark Matter Cosmic Probes
Primordial Black Holes & Gravitational Waves	N	Y	CF03	Dark Matter Cosmic Probes
Numerical simulations and systematics	N	Y	CF03	Dark Matter Cosmic Probes
Dark matter physics in extreme astrophysical environments	N	Y	CF03	Dark Matter Cosmic Probes
Facilities for cosmic probes of dark matter physics	N	Y	CF03	Dark Matter Cosmic Probes
Large number of linear modes (N_{linear})	N	Y	CF03	Dark Energy & Cosmic Acceleration
High density, nP	N	Y	CF03	Dark Energy & Cosmic Acceleration
High precision in Astrophysics	N	Y	CF04/05/06	Dark Energy & Cosmic Acceleration
Enabling flagship experiments to reach their potential	N	Y	CF04/05/06	Dark Energy & Cosmic Acceleration
Theory: Inflationary scienc through non-gaussianity, primordial features, and B-modes	N	Y	CF05	Dark Energy: Cosmic Dawn
Theory: Light relics	N	Y	CF05	Dark Energy: Cosmic Dawn
Theory: BSM Cosmology	N	Y	CF05	Dark Energy: Cosmic Dawn
Theory: Beyond Standard Cosmology	N	Y	CF05	Dark Energy: Cosmic Dawn
Measurement: Stochastic GW Background	N	Y	CF05	Dark Energy: Cosmic Dawn
Measurement: 21 cm	N	Y	CF05	Dark Energy: Cosmic Dawn
Measurement: mm-Wave LIM	N	Y	CF05	Dark Energy: Cosmic Dawn
Measurement: CMB	N	Y	CF05	Dark Energy: Cosmic Dawn
Measurement: Optical Survey	N	Y	CF05	Dark Energy: Cosmic Dawn
Importance/power of joint analysis for "static" science (LSS x CMB/mm/X-ray, etc.)	N	Y	CF06	Complementarity of Probes & New Facilit
Importance/power of joint analysis for "transient" science (LSS x GW, different GW probes, SN other transients, etc.)	N	Y	CF06	Complementarity of Probes & New Facilit
Importance of cross-collaboration infrastructure	N	Y	CF06	Complementarity of Probes & New Facilit
Multimessenger facilities and experiments	N	Y	CF07	Cosmic Probes

Axion Dark matter

Massive Spectroscopic Telescope

CMB S4 and a Massive Spectroscopic Telescope

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Neutrino WG Retreat Summary

Current lab efforts concentrated on Short Baseline Neutrino Program and LBNF/DUNE

- MicroBooNE first results on MiniBooNE LEE; To be followed by SBN oscillation, BSM & neutrino xsec measurements
- Advancing DUNE through design & prototyping efforts; neutrino mass ordering (hierarchy), leptonic CP violation, and the nature of mu-tau mixing starting early in the next decade.

Fermilab interest in the following areas beyond SBN/DUNE:

- Expanded physics scope with the DUNE far detector modules (including the 4th “module of opportunity”), including low energy astrophysical signals and searches for rare processes such as neutrinoless double-beta decay.
- Efforts targeting improved modeling of neutrino-nucleus interactions, which will be key to reaching the full CP-violation sensitivity of DUNE.
- Neutrino physics with high-intensity stopped pion beams.
- Neutrino physics with stored muons, allowing precise measurements of oscillations in a variety of channels using precisely known neutrino energy spectra.
- Tau neutrino appearance measurements, allowing direct tests of the unitary of neutrino mixing not possible elsewhere.

All areas have leading Snowmass contributions from FNAL scientists.

Detector WG Retreat Summary (1/2)

Detectors for the Neutrino Frontier

- Near future: many efforts related to DUNE, such as pixelated readout, cold readout electronics (ASICs), photodetectors for instrumenting high voltage surfaces for the Vertical Drift module, high pressure GAr-TPC, in HV environment, 3-D scintillation tracker (3DST) for near detector (see also Energy Frontier)
- Growing interest for reducing energy thresholds of LAr-TPCs (scintillation light & drift charge) for applications in neutrino physics (recovering missing energy, Supernovae neutrino, coherent neutrino scattering CEvNS) and dark matter
- Magnetizing LAr-TPCs

LOI's/White Papers in preparation, also in conjunction with other Universities/Labs: directional nuclear recoil searches with GAr-TPC's, Multi-modal Pixels for Noble Element Time Projection Chambers, Dual-Readout Time Projection Chamber, magnetization of LAr-TPC, Metalenses as light concentrators in noble element detectors

Detectors for the Energy Frontier

The Fermilab's detector R&D efforts in EF are fully aligned with the Grand Challenges identified in the DOE BRN document and critical to design detectors at future e+e-, mu+mu-, pp machines

- Future tracking detectors require high granularity, precision timing, low mass, radiation hardness (Fermilab involved in: 4D-tracker R&D with 3DIC, AC buried layer LGADs, Induced current silicon detectors)
- Future calorimeters require high granularity, precision timing, radiation hardness (Fermilab involved in: Silicon Tungsten calorimetry and SiPM on scintillator technology)
- Future detectors require new technologies to cope with increased data rates (Fermilab involved in: High-speed rad hard links and intelligent on/off-detector real-time electronics using ML)
- Future mega experiments require economical technology (Fermilab involved in: Scintillator extrusion for Mathusla)

White papers are being prepared in collaborations with users' community

Detector WG Retreat Summary (1/2)

Detectors for the Cosmic Frontier

- DM wave detection:
  - Cryogenic detector R&D for dark matter searches
  - ADMX-EFR, BREAD; Synergy with quantum sensor efforts at FNAL
- Technology for future Cosmic Surveys (DM+DE)
  - Axion dark matter searches: multiple efforts in new detection technologies
  - skipper-CCD in astronomical instruments in collaboration with NSF (NOIRLab); High density fiber positioners
- CMB
  - CMB-S4 : detector module and assembly; MKID based spectrometers for CMB
- Particle Dark Matter
  - Technology for future spectroscopic surveys, including Skipper CCDs and Fiber Positioners
  - Skipper-CCD developments (lead by FNAL for DM, neutrinos, QIS); Readout electronics for low threshold experiments; Nexus facility for sub-GeV dark matter with cryogenic detectors

Detectors for the Precision Frontier

- R&D for future mu2e experiments
- Radiation hard detectors, fast rad-hard calorimeter, ultra low mass tracker, high efficiency cosmic ray veto system, high power rad-hard POI delivery, sub-ns electronics/trigger

Accelerator WG Retreat Summary (1/2)

Accelerator and Beam Physics. In the next decade,the primary focus of scientific mission for ABP is to resolve its grand challenges identified in following categories: **1) Beam Intensity:** Increase in beam intensities by several order of magnitudes, **2) Beam Quality:** Improvement in beam quality to increase phase space density by several order of magnitude, **3) Beam Control:** Precise measurement and control down to individual particle level, and **4) Beam prediction:** Developing tools for accurate prediction of the beam.

Fermilab is actively engaged in large scale global projects such as: International Linear Collider (ILC), Future Circular Collider (FCC) and Muon Collider Collaboration (MCC) and participating in a number of experiments and testing advanced accelerator concepts at FACET-II beam test facility at SLAC.

SRF. Superconducting radiofrequency (SRF) cavities are an enabling technology on several frontiers of HEP: **1) Energy Frontier:** linear electron colliders (ILC), circular electron colliders (FCC-ee/CepC), protons (HL-LHC, SppC), **2) Intensity & Precision Frontiers:** proton drivers (PIP-II/PIP-III), and **3) Quantum Frontier:** high Q0 resonators in the regime of low temperature and low photon count

Fermilab organized and hosted a 2018 workshop to plan research directions for SRF R&D under the **DOE GARD** (General Accelerator RD) program. This resulted in roadmaps for pushing accelerating gradient and Q0 for the next decade.

Accelerator WG Retreat Summary (2/2)

Magnets: Superconducting magnets are the enabling technology for Energy Frontier circular electron colliders (FCC-ee/CepC) and proton colliders (HL-LHC, SppC). **1) Development of accelerator magnets at the limit of the Nb3Sn capabilities 2) Development of a hybrid magnet with a 15 T Nb_3Sn dipole and a 5 T HTS magnet insert,** and **3) Development of superconducting undulators.**

R&D efforts performed at FNAL aligns well with the Snowmass (and elsewhere) process started in 2020. More than 1/3 of the LOI presented at Snowmass are connected with the MDP program through a principal investigator or collaborator. The themes and the research directions explored at FNAL show a strong synergy with what has been proposed and discussed as Letter of Interest in the Snowmass process.

High Power Targets. Materials R&D: **1) Evaluate material response** under prototypic multi-MW conditions and Investigate alternative to proton beams for thermal shock, radiation damage, fatigue study, **2) Develop and benchmark required simulation/modeling methods** to guide the development of alternative techniques, **3) Discover/design new radiation and thermal shock compatible materials.** Advanced Targetry Technologies: **1) Robotic remote handling technologies** (e.g. machine vision/learning), **2) Advanced manufacturing technologies** (e.g. additive manufacturing), **3) Online target health monitoring**, and **4) Novel target concepts.**

The R&D efforts conducted at FNAL is well aligned with the Snowmass process started in 2020. All the high and medium priorities of Fermilab R&D program are represented in the main topics identified from the Letter of Interest received at the early stage of Snowmass process. High Power Targetry community is highly engaged through the Snowmass process and the **RaDIATE collaboration**.

Computing WG Retreat Summary

Fermilab's Scientific Computing Division is engaged in computing R&D for near-term next-generation experiments like DUNE and the upgraded CMS for the HL-LHC.

Planning the future of HEP computing is unlike other planning efforts due to its primarily reactive posture toward the changing computing landscape.

For new experiments targeting 2030 and later it is possible to estimate the computing needs, however the computing resources available and computing solutions are unknown.

Until we know the general computing direction from DOE, targeting 2030 is very difficult.

Large expertise base in software and storage is available to begin R&D with emerging technologies as we gain a better picture of future needs.

Members of the Scientific Computing Division have submitted 22 Snowmass letters of interest that discuss computing challenges in HEP, such as data processing in a supercomputing environment, data storage and analysis, improving particle tracking using machine learning, neutrino event generators, etc.

SAC SWG Retreat Summaries in All-Scientist Quarterly Meeting

We plan to have follow up discussions of the All-Scientist Retreat in upcoming All-Scientist Quarterly meetings *(first one planned for on Dec 3)*

Opportunity to have a more formal assessment of where we are…

- Review of Fermi Scientists' interests/priorities
- Will request more details on the status/plans for white paper submissions
- Discuss post-snowmass strategy

Will prepare a summary document (as was done for the 2019 all-scientist retreat)

Snowmass-Fermilab Lectures/Symposia

Planning is underway to organize a series of joint Snowmass-Fermilab lectures and discussions on various themes of mutual interest.

Future Colliders series is being organized jointly by:

Snowmass EF, AF and Fermilab Future Colliders Group (FCG), from December '21 – April '22.

- 3 – 5 pm on Wednesdays, ~once a month; Hosted by Fermilab
- Program committee: J. Butler, M. Narain, A. Tricoli, L. Reina, V. Shiltsev, P. Bhat
- Brief presentations on physics and technical aspects of proposed colliders and emerging concepts, followed by discussions led by moderators.

Tentative Schedule and Themes (different classes of colliders)

- Dec. 15, 2021: Linear ee (ILC, CLIC, C^3, ERL-based, FNAL site fillers)
- Jan. 19, 2022: Circular ee (FCCee, CepC, LEP3, ERL-based, FNAL site filler)
- Feb. 16, 2022: Muon colliders (125 GeV, 3-14+ TeV, FNAL site filler)
- Mar. 16, 2022: Circular pp/ep (FCChh, SPPC, LHeC, FCCeh, FNAL Site Filler)
- Apr. 13, 2022: Advanced colliders (laser- and beam-plasma, DWA, etc)

A "Colliders discussion" will be organized during the Snowmass Energy Frontier Meeting planned for the week of March 28.

Goals will be to develop a R&D road map and propose demonstrators for possible inclusion in P5...

FY22 Strategic Planning Workshop – Snowmass-focused

Office of Integrated Planning and Performance Management (IPPM) is responsible for science-related strategic planning

Planning for the FY22 Strategic Planning Workshop.

Participants: SAC Working Groups, Strategic Planning Group Leaders, Senior Management Representatives...

Goals: Discuss Fermilab-centric view of long-term plans; How can Fermilab serve the broader physics community and facilitate opportunities?

Workshop format under discussion

- Each SAC Working Group presents what they believe will be top priorities at Snowmass for their frontier
- Breakout groups discuss and add/modify list
- Each SPGL presents major initiatives/timelines for next 5-10 years at Fermilab
- Breakout groups discuss presentations in the context of longer-term planning and guidance from Directorate

Summary

Effectiveness of organization

Established the SAC Scientific Working groups in 2019

Fermilab Scientists played a major role in the 2020 Community Planning Meeting

Fermilab Scientists are well integrated into the Snowmass organization

SAC organized the all-scientist retreat to restart the Snowmass effort

SAC organizes regular meetings to inform the Scientists and to encourage wide participation

Snowmass participation

SWGs have identified FNAL Scientists' areas of interest and there is good representation across all areas

Good engagement by individuals in Snowmass and with the preparation of white papers

Follow up discussions are planned for in all-scientist's meetings (first one on Dec 3)

Role of the Lab / Post-Snowmass Planning (P5)

Host Snowmass-Fermilab Lectures/Symposia -> discuss post-Snowmass strategy

FY22 Strategic Planning Workshop - Snowmass-focussed

Strong engagement from Fermilab scientists mostly done on an **individual basis**

We are on track to making significant contributions to the white papers

Points for Discussion

Good engagement in the Snowmass process *-> discuss developing the post Snowmass strategy*

Scientific Working Groups could play a greater role in coordinating the FNAL effort and to help develop a comprehensive plan for FNAL *-> coverage for all areas...*

Could be achieved by sharpening the mandate for the SAC Scientific Working groups

- *Would be helpful to have more clear guidance from the Lab on the role of the SWGs and how feedback would be used for the Lab prioritization and strategic planning in general*
- *Status reports directly to upper management, helps ensure priority alignment and helps to empower SWG convenors (via FY22 Strategic Planning Workshop)*
- *Improve coordination between SWG and IPPM (define formal role of SWG)*

We would welcome a more inclusive/transparent process for how the lab will proceed with the post snowmass prioritization (for P5)

The SWGs could play a role in helping to develop the lab's post-snowmass strategy

BACKUP Slides

Past PAC Recommendations

July 2019:

- The PAC welcomes the **improved communication between SAC and IPPM.**
- The PAC recommends that the Laboratory consider **organizing a timely workshop** dedicated to Snowmass to which the HEP community is invited, as proposed by the SAC.

  CPM: Oct 5-8, 2020

July 2020:

- The PAC acknowledges that the Snowmass process is very time consuming, and that the scientists involved in the Snowmass process have important responsibilities in detector operations, computing and analyses. The load represented by the **preparation of the Snowmass LOI should be recognized and accounted for.**

All-Scientist Quarterly Meetings

Quarterly Meetings with All-Scientists

- Focus on issues relevant to SAC, including Snowmass topics
- Open channels for dialogue
- Recent All-Scientist Quarterly meetings: https://indico.fnal.gov/category/905/

  Jan 31 2020, May 29, 2020*, Aug 14, 2020, Aug 21, 2020*, Dec 4 2020*, Apr 2, 2021*, Jun 4, 2021, Aug 4, 2021** (* Snowmass focus)

Communicate status updates and opportunities from Frontier/Topical conveners

Discuss best ways to participate in Snowmass, distribute information

Encourage and track white papers, cross-pollinate ideas between different Frontiers

Snowmass Frontiers (1/2)

Fermilab Scientists have convenorship roles within the Snowmass organization

- Energy Frontier
  - EF05: QCD and strong interactions: Precision QCD (Stefan Hoeche)
  - EF08: BSM: Model specific explorations (Jim Hirschauer)
- Neutrino Physics Frontier
  - NF02: Understanding Experimental Neutrino Anomalies (Pedro Machado)
  - NF09: Artificial Neutrino Sources (Laura Fields)
- Rare Processes and Precision (Bob Berstein)
- Cosmic Frontier (Aaron Chou)
  - CF3: Dark Matter: Cosmic Probes (Alex Drlica-Wagner)
  - CF4: Dark Energy and Cosmic Acceleration: The Modern Universe (Jim Annis)
  - CF6: Dark Energy and Cosmic Acceleration: Complimentary of Probes and New Facilities (Brenna Flaugher)
- Theory Frontier
  - TF08: BSM Model Building (Patrick Fox)
  - TF10: Quantum Information Science (Roni Harnik)
- Accelerator Frontier (Vladimir Shiltsev)
  - AF2: Accelerators for Neutrinos (Bob Zwaska)
  - AF4: Multi-Tev Colliders (Alexander Valishev)
  - AF7: Accelerator Technology: RF (Sergey Belometnykh)
  - AF7: Accelerator Technology: Magnets: (Sasha Zlobin)
  - AF7: Accelerator Technology: Targets/Sources (Frederique Pellemoine)

Snowmass Frontiers (2/2)

Fermilab Scientists have convenorship roles within the Snowmass organization

- Instrumentation Frontier (Petra Merkel)
  a. IF2: Photon Detectors (Juan Estrada)
  b. IF3: Solid State Detectors and Tracking (Artur Apresyan)
  c. IF4: Trigger and DAQ (Wes Ketchum)
  d. IF8: Noble Elements (Jen Raaf)
- Computational Frontier (Daniel Elvira)
  a. CompF1: Experimental Algorithm Parallelization (Giuseppe Cerati)
  b. CompF2: Theoretical Calculations and Simulations (Daniel Elvira)
  c. CompF6: Quantum Computing (Gabriel Perdue)
- Underground Facilities
- Community Engagement
  a. CommF1: Applications and Industry (Farah Fahim)
  b. CommF5: Public Education and Outreach (Don Lincoln)
  c. CommF6: Public Policy and government Engagement (Louise Suter)

Snowmass Restart

- In parallel to the **Snowmass process restarting in September**, we resumed FNAL-internal planning & discussions
  - For announcements & timelines of the Snowmass process see https://snowmass21.org/announcements
- **Snowmass Day: September 24, 2021**
  - Review plans forward for all Frontiers
  - Virtual meeting
  - Plenary and breakout sessions

  For details refer to the Snowmass website
- Snowmass Community Summer Study (**CSS**) to be held the University of Washington-Seattle **July 17-27, 2022**.
- **Timeline:**
  - White Paper submission to arXiv: no later than March 15, 2022. Late submissions and updates are likely not to be incorporated in the working group reports, but will be included in the Snowmass online archive documents.
  - Preliminary reports by the Topical Groups due: no later than May 31, 2022.
  - Preliminary reports by the Frontiers due: no later than June 30, 2022.
  - Snowmass Community Summer Study (CSS): July, 2022 at UW-Seattle.
  - All final reports by TGs and Frontiers due: no later than September 30, 2022.
  - Snowmass Book and the online archive documents due: October 31, 2022.

Goals for the Community Planning Meeting

- The primary goal:
  - **Develop plans and steps to take (“Snowmass Planning”) between October 2020 and the Snowmass Community meeting (July 17-27, 2022), leading to a final report in October 2022.**

- Other goals include:
  - Inspire the community about the field, and encourage them to engage broadly in the Snowmass process
  - Inform the community about plans from other regions and from related fields and planned Snowmass activities
  - Listen to the community
  - **Provide space for members across the field to talk to each other and to discuss, promote, and develop new ideas**
  - **Establish cross working-group connections and identify gaps**

CPM Organization

Organizing Committees

Program Committee

- *Snowmass Steering Group*: Young-Kee Kim, Tao Han, Joel Butler, Prisca Cushman, Sergei Nagaitsev, Yury Kolomensky, Glennys Farrar, Gabriela Gonzales
- *Frontier Conveners*: Laura Reina (EF), Patrick Huber (NF), Marina Artuso (RF), Aaron Chou (CF), Aida El-Khadra (TF), Tor Raubenheimer (AF), Jinlong Zhang (IF), Oliver Gutsche (CompF), John Orrell (UF), Breese Quinn (CommF)
- *Early Careers*: Vishvas Pandey (postdoc), Joshua Barrow (graduate student)
- *Local Organizing Committee* (Ex-officio Members) Bo Jayatilaka, Brendan Kiburg

Local Organizing Committee

- Jonathan Asaadi, Saptaparna Bhattacharya, Zoltan Gecse, Shih-Chieh Hsu, Bo Jayatilaka (co-chair), Brendan Kiburg (co-chair), Erica Snider, Tiziana Spina, Gordon Watts, Yuanyuan Zhang

- The scientific program was developed by the Program Committee which tried to balance competing interests, and was advised by steering group
- The LOC implemented the meeting logistics
  - Learned from hosting Neutrino 2020 and Users' Meeting virtually
  - Overlap with LOC for those two meetings, as well as CSS 2021

All-Scientist Retreat 2021: Charge for Frontier Groups

Cosmic, Energy, Neutrinos, Precision

Based on the list of 2030-era experiments developed at the 2019 Scientist Retreat, and including any new effort that has emerged since then, assign a level of interest (high, medium, or low) for each of the experiments.

For each experiment, list the goal (i.e. discovery, limit, potential) that the experiment enables and what factors used to rank each experiment.

Which experiments would have the greatest impact for advancing your sub field?

Of these experiments, what effort would Fermilab need to contribute and what would be needed to engage broader Fermilab participation?

Discuss how the current effort at Fermilab is aligned with the identified future experiments and interest levels.

Evaluate if the current Fermilab Snowmass effort is aligned with these priorities.

Discuss how to ensure that the experiments with highest interest / impact are included in the P5 report.

Evaluate what resources (expertise, people, facilities) would be needed for Fermilab to have a major role in leading and executing the high impact experiments.

Provide a timeline outlining the remaining engagement for the Fermilab Scientific Working Group between now and the conclusion of the P5 report. This should include, planned events, submission deadlines, and indicate milestones for group work.

All-Scientist Retreat 2021: Charge for Technology Groups

Accelerators, Computational, Detectors, Quantum

Based on the list of future technologies discussed in the 2019 retreat, and including any new effort that has developed since then, assign a level of interest (high, medium, or low) for each future technology area.

Which technologies are most important for advancing your sub field? For these technologies, which have the potential for Fermilab to take on leading roles and utilize capabilities that are unique to the lab?

For each future technology area, list the advances that the technology enables and what factors were used to rank them.

How do current R&D efforts align with these priorities and set the path to accomplish 2030-era technology goals?

Evaluate if the current Fermilab Snowmass efforts are aligned with these priorities and what is needed to engage a larger community.

Evaluate what resources (expertise, people, facilities) would be needed for Fermilab to have a major role in leading and developing future technologies.

Snowmass White Papers

https://docs.google.com/spreadsheets/d/e/2PACX-1vR9qzpGCj-WLAh9UflFIuitWUGToOCLoQW5Tt4YQIba1hmKtMYPuaCMnHHYyrjaxW_fWaXBSJvDYKRm/pubhtml#

White Paper Submission Database

Overall | EF | **NF** | RPF | CF | TF | AF | IF | CompF | UF | CommF | Complementarity Reports

Neutrino Physics Frontier: https://snowmass21.org/neutrino/start

(Proposed) Title or Topic	Is this being submitted on behalf of the Snowmass Early Career (SEC) group?	Is this White Paper solicited?	Submission Frontier(s) & Topical Group(s)	Main Topic(s)/Keywords	Coordinator Contact Email(s)
https://docs.google.com/spreadsheets/d/1ORQe5LYSaLQ7rsg7UihlD485cUDAxWlb9qZsOlgutIs/edit?usp=sharing	—	—	—	—	Kate Scholberg
Tau Neutrinos: from GeV to EeV	N		NF01, NF03, NF04, NF06, NF08/TF11, NF09, N	Tau Neutrinos	Peter Denton
Theoretical tools for neutrino scattering: the interplay between lattice QCD, EFTs, nuclear physics, phenomenology, and neutrino event generators	N		NF06: Cross Sections, TF11: Theory of Neutrino Physics, TF, CompF, RPF		Saori Pastore
Theory for neutrinoless double beta decay	N		NF06: Cross Sections, TF11: Theory of Neutrino Physics, TF, CompF, RPF		Vincenzo Cirigliano
Future Advances in Photon-Based Neutrino Detectors	N		NF10: Neutrino Detectors, IF, CompF		Joshua Klein
Neutrino Self-Interactions: A White Paper	N		NF03: BSM, NF05: Neutrino Properties, TF11: Theory of Neutrino Physics, TF		Kevin Kelly
Fixed-Target Searches for New Physics with O(10 GeV) Proton Beams at Fermi National Accelerator Laboratory	N		NF03: BSM;NF09: Artificial Neutrino Sources;NF10: Neutrino Detectors, RPF		Matthew Toups
Fixed-Target Searches for New Physics with O(1 GeV) Proton Beams at Fermi National Accelerator Laboratory	N		NF02: Sterile Neutrinos;NF03: BSM;NF06: Cross Sections;NF09: Artificial Neutrino Sources;NF10: Neutrino Detectors, AF;RPF		Matthew Toups
White Paper on Cosmological Neutrinos	N		NF01: Neutrino Oscillations, NF02: Sterile Neutrinos, NF03: BSM, NF04: Neutrinos from Natural Sources, NF05: Neutrino Properties, TF11: Theory of Neutrino Physics, CF		Evan Grohs
Sennsitivity to neutrinoless double beta decay in Xe-136 of a third generation liquid xenon TPC experiment	N		NF05 (+ overlaps with CF)		Kate Scholberg
Fundamental properties of neutrinos from the point of view of cosmology	N		NF01, NF02, NF03, NF05, TF11 (+ overlaps with CF, TF, CompF)		Ibles Olcina
Neutrinos and intergalactic communication problems.	N		NF01, NF02, NF04, NF05, NF06, NF07, TF11, NF09, NF10		Alexander Bonilla Rivera
Particle Physics With Reactor Antineutrinos	N		NF01, NF02, NF03, NF05, NF09, NF10		Paul Shapshak
Low Energy Physics in Liquid Argon	N		NF01, NF02, NF03, NF04, NF06, TF11, NF09, NF10 (+ overlaps with CF, TF, UF)		Bryce Littlejohn
Electron Scattering and Neutrino Physics: A Snowmass White Paper	N		NF06, TF11		Kate Scholberg
Kilotonne-scale xenon detectors for new physics searches	N		NF03, NF05, NF10 (+ overlaps with IF)		Vishvas Pandey
Neutrino Scattering Measurements on Hydrogen and Deuterium	N		NF01, NF02, NF03, NF05, NF06, TF11, NF10 (+ overlaps with TF, RPF)		David Moore
					Richard Hill, Thomas Junk

Fermilab

Neutrino WG White papers

Snowmass NF ID (If present)	Title/Topic	Status	FNAL Role
1	**Tau Neutrinos (broad-span, general paper)**	Drafting in progress	None known.
2	**Theoretical tools for neutrino scattering: the interplay between lattice QCD, EFTs, nuclear physics, phenomenology, and neutrino event generators**	Unknown	Unknown
4	**Future Advances in Photon-Based Neutrino Detectors**	Unknown	Unknown
5	**Neutrino Self-Interactions: A White Paper**	Unknown	Contact was Fermilab at the time the effort started, current Fermilab involvement is Unknown
6	**Fixed-Target Searches for New Physics with O(10 GeV) Proton Beams at Fermi National Accelerator Laboratory (more DM than neutrinos)**	Update pending	Leadership, additional contributions
7	**Fixed-Target Searches for New Physics with O(1 GeV) Proton Beams at Fermi National Accelerator Laboratory**	Update pending	Leadership, additional contributions
8	**White Paper on Cosmological Neutrinos**	Unknown	Unknown
11	**Fundamental properties of neutrinos from the point of view of cosmology**	Unknown	Unknown
14	**Low Energy Physics in Liquid Argon**	Drafting in progress	Several Fermilab contributors
15	**Electron Scattering and Neutrino Physics: A Snowmass White Paper**	Drafting in progress	At least one Fermilab contributor.
17	**Neutrino Scattering Measurements on Hydrogen and Deuterium**	Drafting in progress	Leadership, additional contributions
18	**BSM effects on neutrino flavor**	Unknown	Unknown
	Other cross-section papers	Unknown	Leadership via NuSTEC, other roles, likely substantial contributions.
	DUNE physics scope with 2.4 MW booster replacement	DUNE is working on this.	Unknown.
	Various theory contributions	Unknown	
	NuSTORM	Unknown	Fermilab involvement via leadership of Test Facilities WG of new International Muon Collider Collaboration
	Expanded physics scope with 4th DUNE module	Update pending	Contributions expected.

Detectors for the Neutrino Frontier

Topics that Fermilab scientists are mostly interested in emerged from retreat discussions

- In the near future, mainstream topics related to DUNE detectors:
  - Pixelated detectors, cold readout electronics (ASICs), photodetectors for instrumenting high voltage surfaces for the Vertical Drift module, high pressure GAr-TPC, 3-dimensional scintillation tracker (3DST) for Near Detector (see Energy Frontier)
- Growing interest for reducing energy thresholds of LAr-TPC's both in terms of scintillation light and drift charge, for applications in neutrino physics (recovering missing energy, Supernovae neutrino, coherent neutrino scattering CEvNS) and dark matter
  - Studies of scintillation light properties, proportional scintillation and charge amplification in LAr, doping of LAr with methane+Xe and with photoionizing elements, infrared light in LAr, search for directional nuclear recoil in GAr-TPC equipped with GEM's, combined readout of light and charge with pixel detectors
- Effort for magnetizing LAr-TPC's

LOI's/White Papers in preparation (in conjunction with other Universities/Labs):

Directional nuclear recoil searches with GAr-TPC's, Multi-modal Pixels for Noble Element Time Projection Chambers, Dual-Readout Time Projection Chamber, magnetization of LAr-TPC, Metalenses as light concentrators in noble element detectors

Detectors for the Energy Frontier

The Fermilab's detector R&D efforts in EF are fully aligned with the Grand Challenges identified in the DOE BRN document and critical to design detectors at future e+e-, mu+mu-, pp machines

- Future tracking detectors require high granularity, precision timing, low mass, radiation hardness (Fermilab involved in: 4D-tracker R&D with 3DIC, AC buried layer LGADs, Induced current silicon detectors)
- Future calorimeters require high granularity, precision timing, radiation hardness (Fermilab involved in: Silicon Tungsten calorimetry and SiPM on scintillator technology)
- Future detectors require new technologies to cope with increased data rates (Fermilab involved in: High-speed rad hard links and intelligent on/off-detector real-time electronics using ML)
- Future mega experiments require economical technology (Fermilab involved in: Scintillator extrusion for Mathusla)

White papers are being prepared in collaborations with users' community

EF Detectors subgroup is represented in the newly formed **Fermilab Future Collider group** and reports at All-scientist retreats

- During the recent All-scientists retreat it has been identified that succession planning for personnel and continued support for maintaining lab equipment is critical for the laboratory to carry out R&D in the near future.

Detectors for the Cosmic Frontier

Discussed interest and involvement of FNAL in the instrumentation efforts and the associated white papers.

- DM wave detection:
  - ADMX-EFR, BREAD
  - Synergy with quantum sensor efforts at FNAL
- Technology for future Cosmic Surveys (DM+DE)
  - skipper-CCD in astronomical instruments in collaboration with NSF (NOIRLab)
  - High density fiber positioners
- CMB
  - CMB-S4 : detector module and assembly
  - MKID based spectrometers for CMB
- Particle Dark Matter
  - Skipper-CCD developments (lead by FNAL for DM, neutrinos, QIS)
  - Readout electronics for low threshold experiments
  - Nexus facility for sub-GeV dark matter with cryogenic detectors

The discussion time focused on how to protect and increase the engineering and technical expertise at the lab for these technologies.

Detectors for the Precision Frontier

Series of workshops on mu2e-II - main focus with strong representation

R&D needs for future mu2e experiments:

- Radiation hard electronics
  - Component qualifications is needed
- Fast rad hard calorimeter
  - <10% energy resolution and 500ps timing
  - ~1MRad and 1013n_1MeV/cm2
- Ultra low mass tracker
  - <0.1% X0 with <100ps TOF tracking for PID
- High efficiency cosmic ray veto system
  - >99.99% efficiency, neutron fluency issue on SiPM/scintillator
- High power, rad hard POL delivery
  - Radiation and B-field hard DC/DC converters
- Sub-ns electronics/trigger

Accelerator WG Summary

Exploring and developing science for advanced accelerator concepts, seeking and incorporating new technologies to make cheaper, safe and reliable particle accelerators for fundamental high energy physics research as well as to address societal problems including but not limited to transmutation, radiotherapy, medical isotopes etc.

In the next decade to come, the primary focus of scientific mission for ABP is to resolve its grand challenges identified in following categories:

- Beam Intensity: Increase in beam intensities by several order of magnitudes.
- Beam Quality : Improvement in beam quality to increase phase space density by several order of magnitude
- Beam Control : Precise measurement and control down to individual particle level.
- Beam prediction: Developing tools for accurate prediction of the beam.

In addition to above grand challenges, ABP mission also aims at:

- Development of conventional and novel accelerator concepts and tools to dispense existing costly technology model.
- Advance physics of accelerators and beams to enable future accelerators
- Guiding and helping for a complete utilization of science at existing operational accelerator and beam facilities
- Educate and train future accelerator physicists.

Fermilab is systematically upgrading its existing accelerator complex under Proton Improvement Plan (PIP) to deliver a beam power in excess of mega-watt.

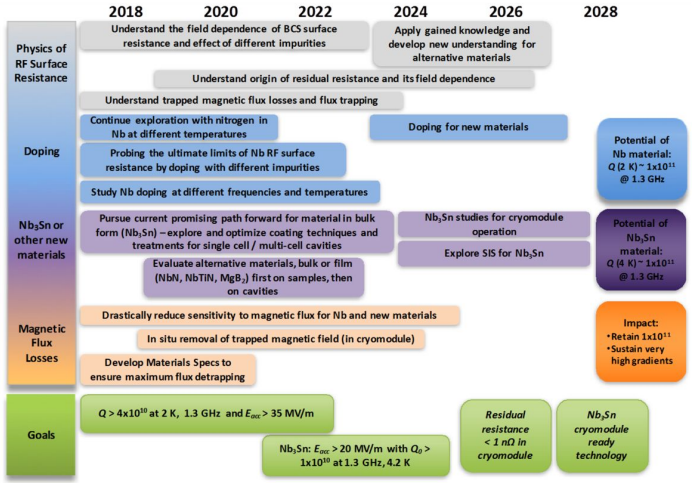
Fermilab is actively engaged in large scale global projects such as: International Linear Collider (ILC), Future Circular Collider (FCC) and Muon Collider Collaboration (MCC). A team of Fermilab scientists has also been participating in a number of experiments and testing advanced accelerator concepts at FACET-II beam test facility at SLAC.

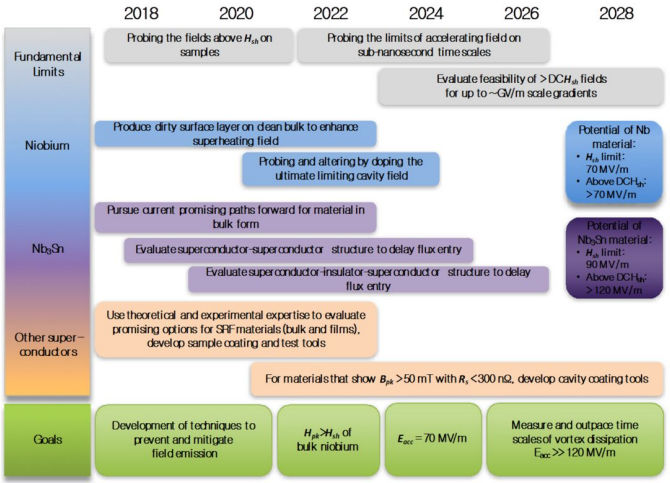
Accelerator WG Summary: Superconducting RF Cavities

Superconducting radiofrequency (SRF) cavities are an enabling technology on several frontiers of HEP:

- **Energy Frontier:** linear electron colliders (ILC), circular electron colliders (FCC-ee/CepC), protons (HL-LHC, SppC)
- **Intensity & Precision Frontiers:** proton drivers (PIP-II/PIP-III)
- **Quantum Frontier:** high Q0 resonators in the regime of low temperature and low photon count

Fermilab organized and hosted a 2018 workshop to plan research directions for SRF R&D under the DOE GARD (General Accelerator RD) program. This resulted in roadmaps for pushing accelerating gradient and Q0 for the next decade.





Fermilab is leading a vibrant and innovative SRF R&D program aligned with the GARD road map and more broadly to the DOE scientific mission.

The successfulness of this R&D program will allow future accelerators for all the HEP frontiers – high energy, high intensity, and precision.

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Accelerator WG: High Power Targets

Materials R&D

High: Evaluate material response under prototypic multi-MW conditions and Investigate alternative to proton beams for thermal shock, radiation damage, fatigue study
Medium: Develop and benchmark required simulation/modeling methods to guide the development of alternative techniques
Medium: Discover/design new radiation and thermal shock compatible materials.

Advanced Targetry Technologies

Medium: Robotic remote handling technologies (e.g. machine vision/learning)
Low: Advanced manufacturing technologies (e.g. additive manufacturing)
Low: Online target health monitoring
Low: Novel target concepts

RaDIATE collaboration led by FNAL, including 14 participating international institutions, covers research on radiation behavior and thermal shock on material but also supports Correlation of micro-mechanics to macro-properties, novel target design concept.

The R&D efforts conducted at FNAL is well aligned with the Snowmass process started in 2020. All the high and medium priorities of Fermilab R&D program are represented in the main topics identified from the Letter of Intents received at the early stage of Snowmass process. High Power Targetry community is highly engaged through the Snowmass process and the RaDIATE collaboration.

The R&D program needs more resources (labor and budget) as we will develop in-house expertise and new in-house facilities to support current development and future operation.

Accelerator WG: White Papers on Targets

LOIs topics

- Material studies to Extend Radiological
- Material Science including irradiation stations development and PIE
- Modelling
- Novel materials and novel target concepts
- Rad-Hard instrumentation
- Remote Handling and operations
- Specialized “Physic” target

Additional topics of interest

- Radioactive waste management
- Manufacturing
- Device health monitoring + integrated ML

White papers

- Irradiation stations and alternatives
  - Compile existing irradiation facilities including PIE
  - Study to correlate irradiation damage from different beams (high energy, low energy, proton, heavy ions, electron)
- Modeling
- Novel material and concept
  - R&D program to develop promising novel material from different lab
- Novel Concepts
  - Powder/granular/pebble bed target
  - Mu2e-II/conveyor target
  - Multi slice rotating target
  - Include PIE capability in the early design process
- Operation
  - Remote handling and radiation protection
  - Device health monitoring (integrated system + ML) and Rad-Hard instrumentation

Accelerator WG: Status of White Papers on Targets

Irradiation stations and alternatives

- Irradiation Stations and Alternatives Workshop held on 17&18 June 2021
- Responsible to organized the white paper identified
- Outline and author identification ongoing

Modeling

- Target Simulations Workshop held on 6 April 2021
- Responsible to organized the white paper identified
- Outline defined
- Author identification ongoing

Novel material and concept

- Responsible to organized the white paper identified
- Outline and author identification ongoing

Device health monitoring (integrated system + ML) and Rad-Hard instrumentation

Accelerator WG: Superconducting Magnets

The work performed at FNAL covers three main research areas:

- Development of accelerator magnets at the limit of the Nb3Sn capabilities:
  - fabricating a strain management cos-theta dipole with a 120 mm aperture

- Development of a hybrid magnet with a 15 T Nb3Sn dipole and a 5 T HTS magnet insert:
  - Fabrication and performance demonstration of both a COMB coil with a REBCO cable and a Bi2212 stress management insert are planned.
  - Computation work for a 20 T hybrid magnet is also undergoing; the work focuses on magnetic and mechanical design and quench protection study.

- Development of superconducting undulators

Accelerator WG: Superconducting Magnets

Essential ingredients for the developments of very high field superconducting magnet (T>20 T): research on materials, quench detection, diagnostic and magnet training reduction.

- Novel magnet materials like thermoplastic or high toughness impregnation resins.
- Advanced magnet diagnostics:
  - fiber optics as diagnostic tool for strain, temperature, and disturbance spectra measurements
  - high-speed/accuracy rotating coil capabilities.
- Novel quench detection system based on:
  - quench antenna system
  - machine learning
  - distributed optical fibers
- Training reduction
  - increasing superconductor performance through development of ACP and high-Cp wires
  - fabricating and testing a capacitor-based quench boosting device (QCD).

Snowmass AF7 magnets: LOIs

- General:
  - 4 magnet R&D programs in the U.S., EU, Japan and China
  - 10 conductor and cable
  - 10 magnet design (HTS, LTS, Hybrid, Fast Cycling HTS magnets)
  - 5 diagnostics, test facilities and cryogenics
- Machines:
  - 3 solenoids for detectors
  - 3 undulators for γγ and linear colliders
  - 4 solenoids and fast cycling magnet for muon colliders
  - 6 low to high field accelerator magnets for hadron colliders
  - 1 beam lines

Snowmass work will restart after MT27 conference In November

Comparison of Planning Groups

SAC Scientific Working Groups

Periodic Working Group Meetings

Prepare to contribute to the next Community Planning Exercise (Snowmass, P5)

Long-term strategic planning (2026+)

Open exploration to identify experiments, facilities to achieve broad physics goals

Internal strategic planning activity that will solicit input from the community and contribute to the broader HEP planning process (Snowmass/P5)

IPPM Strategic Planning Group

Annual Strategic Planning Workshops

Formulate Lab's strategic plan and contribute to DOE/SC Annual Lab Plan

Near-term strategic planning (5-10 years)

Update existing and propose new lab goals and lab objectives

Internal strategic planning activity that communicates the lab's strategic plan to multiple external audiences

By 2022, both groups will be focusing on developing and executing the strategy for the same time period