Perspectives on Snowmass

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The Accelerator Test Facility


Welcome
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Snowmass Community Summer Study Workshop

- Seattle Meeting: July 17-26, 2022
  - Some statistics:
    - ~1200 physicists online and in-person
    - 511 submitted whitepapers
  - Working Areas ⇔ Frontiers (with assigned liaisons to support interconnections)
    - Energy Frontier
    - Neutrino Physics Frontier
    - Rare Processes and Precision Measurements
    - Cosmic Frontier
    - Theory Frontier
    - Accelerator Frontier
    - Instrumentation Frontier
    - Computational Frontier
    - Underground Facilities
    - Community Engagement
- Frontier reports nearing completion and overall summary being prepared

Key Snowmass Engagement for the MC

Muon Collider Forum

- Coordinators:
  - Kevin Black (University of Wisconsin)
  - Sergo Jindariani (FNAL)
  - Derun Li (LBNL)
  - Fabio Maltoni
  - Patrick Meade (Stony Brook University)
  - Diktys Stratakis (FNAL)
- Muon Collider Forum Report: https://arxiv.org/abs/2209.01318

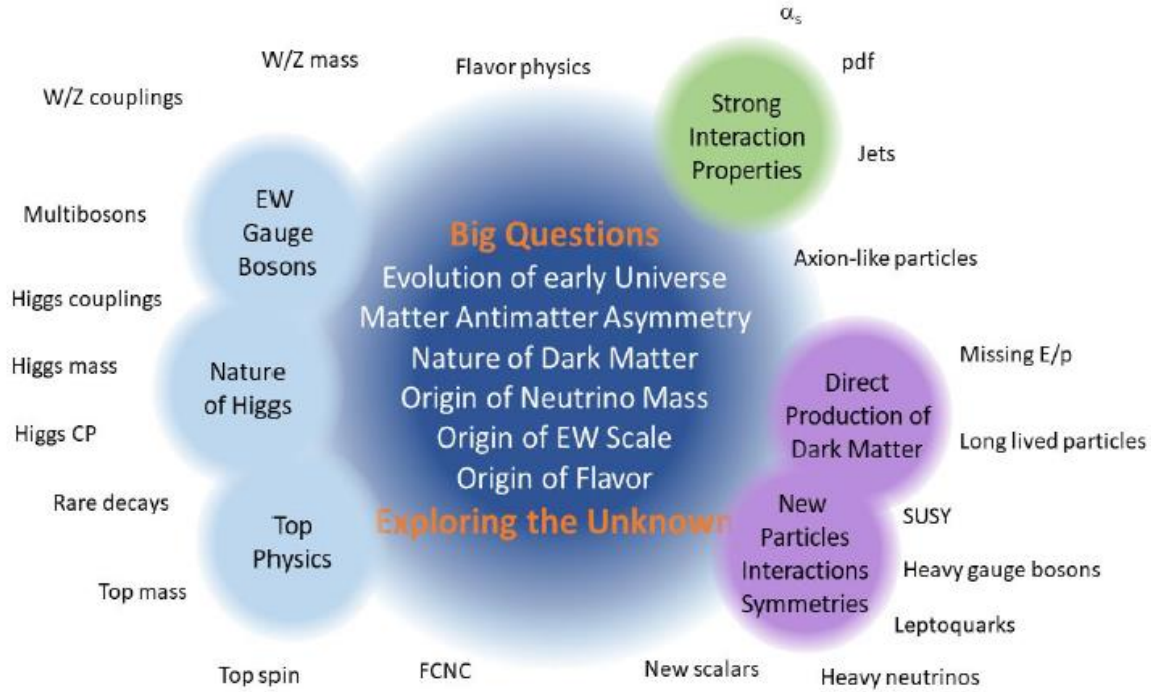
Muon Agora (Feb 16, 2022): https://indico.fnal.gov/event/53010/

Muon Smasher's Guide: https://arxiv.org/abs/2103.14043

And the IMCC Contributions...

Addressing the "**Big Questions**" and "**Exploring the unknown**" are the main scientific goals of the EF

to be pursued following



Two main avenues

- **Study known phenomena at high energies looking for indirect evidence of BSM physics**
  - Need **factories of Higgs bosons** (and other SM particles) to probe the TeV scale via precision measurements
- **Search for direct evidence of BSM physics at the energy frontier**
  - Need to directly reach the **multi-TeV scale**

Energy Frontier Vision

The immediate future is the HL-LHC

- During the next decade it is essential to complete the **highest priority recommendation of the last P5** and to fully realize the scientific potential of the **HL-LHC collecting at least 3 ab^{-1} of data**.
- **Continued stro**
  particular for the
  analyses based
  extend the reac
- **For the next de**
  - **2025-2030**
  - **2030-2035**
  - **After 2035**
    measureme

See Energy Frontier Presentation by L. Reina in "Physics Highlights from the Frontiers" Session July 25, 2022

The intermediate future is an e^+e^- Higgs factory

The intermediate future is an e^+e^- Higgs factory, either based on a linear (ILC, C^3, CLIC) or circular collider (FCC-ee, CepC).

- **The various pr**
  important to rea
- **A fast start tow**
  that could be re
- **For the next de**
  - **2025-2030**
    collider
  - **2030-2035**
  - **After 2035**

The long-term future is a multi-TeV collider

- A 10-TeV **muon collider** (MuC) and 100-TeV **proton-proton collider** (FCC-hh, SppC) directly probe the order 10 TeV energy scale with different strengths that are unparalleled in terms of mass reach, precision, and sensitivity.
- The main limitation is technology readiness. **A vigorous R&D program** into accelerator and detector technologies **will be crucial.**
- **For the next decade and beyond**
  - **2025-2030**:
    - Develop an initial design for a first stage TeV-scale Muon Collider in the US (pre-CDR)
    - Support critical detector R&D towards EF multi-TeV colliders
  - **2030-2035**: Demonstrate principal risk mitigation and deliver CDR for a first-stage TeV-scale Muon Collider
  - **After 2035**:
    - Demonstrate readiness to construct and deliver TDR for a first-stage TeV-scale Muon Collider
    - Ramp up funding support for detector R&D for EF multi-TeV colliders

Accelerator Frontier Messages

Accelerator Frontier "Message"

Snowmass 2021

On Colliders: We need an integrated future collider R&D program to engage in the design and to coordinate the development of the next generation collider projects:

- To address in ar
  challenges of pr
  not covered by
  (GARD) progra
- To enable syner
  efforts (e.g., FC
- To develop colli
  feasible to be h
  Muon Collider, e

See Accelerator Frontier Presentation by S. Gourlay in "Enabling the Physics Goals: Enabling Science" Session July 25, 2022

International MUON Collider Collaboration

Accelerator Frontier "Message"

Snowmass 2021

On R&D: We have an ongoing R&D program aimed at fundamental beam physics and long-term accelerator concepts and technologies (RF, magnets, beam physics, advanced concepts, targets & sources, etc):

- All these items have broad a
  accelerators with ideas gene
- R&D is key to enable facilitie
  and colliders

To Enable Future Accelerators

Snowmass 2021

Three main components:

- To enable the near- to medium-term future:
  1. A National Future Collider R&D Program
- To enable the medium- and long-term future:
  2. General Accelerator R&D (GARD)
  3. Accelerator and Test facilities

Implementation Task Force: Project Comparisons

International MUON Collider Collaboration

From the ITF Report Draft: Tables 1-3, 5

Snowmass 2021

	CME (TeV)	Lumi per IP (10^34)	Years, pre-project R&D	Years to 1st physics	Cost range (2021 B$)	Electric Power (MW)
FCCee-0.24	0.24	8.5	0-2	13-18	12-18	280
ILC-0.25	0.25	2.7	0-2	<12	7-12	140
CLIC-0.38	0.38	2.3	0-2	13-18	7-12	110
HELEN-0.25	0.25	1.4	5-10	13-18	7-12	110
CCC-0.25	0.25	1.3	3-5	13-18	7-12	150
MC-Higgs	0.13	0.01	>10	19-24	4-7	~200
CLIC-3	3	5.9	3-5	19-24	18-30	~550
ILC-3	3	6.1	5-10	19-24	18-30	~400
MC-3	3	2.3	>10	19-24	7-12	~230
MC-FNAL	6-10	20	>10	19-24	12-18	O(300)
MC-IMCC	10-14	20	>10	>25	12-18	O(300)
FCChh-100	100	30	>10	>25	30-50	~560

What Is Needed for Informed Choices?

Collider Concepts	Collider-in-Sea MuIC WFA ReLIC (≤3 TeV) MuC Multi-TeV ILC (Nb_3Sn)... CCC. (TeV) SppC FCC-eh FCC-hh CLIC TeV ILC (Nb)..		
Technical Maturity	• Low maturity conceptual development. • Proof-of-principle R&D required. • Concepts not ready for facility consideration.	• Emerging accelerator concepts requiring significant basic R&D and design effort to bring to maturity.	• Designs have achieved a level of maturity to have reliable performance evaluations based on prior R&D and design efforts. • Critical project risks have been identified and sub-system focused R&D is underway where necessary.
Funding Approach	• Funding for basic R&D required. • Availability of "generic" accelerator test facility access often necessary.	• Efforts would benefit from directed R&D funding to mature collider concepts. • Availability of test facilities to demonstrate a broad range of technology concepts required. • Some large-ticket demonstrators are generally necessary before a detailed "reference" design can be completed.	• Funding approach typically transitions to "project-style" efforts with significant dedicated investment required.

US Collider Interest: Participation & Siting Options

Summary presentation at NA-PAC'22 – MOYD2

Key thrusts:
- Develop U.S. National Accelerator R&D Program on Future Colliders
- Consider emerging site options at Fermilab

Future Colliders Initiative at Fermilab

- A Future Colliders Group (FCG) was formed at Fermilab about a year ago with the following objectives:
  - Develop Fermilab's **engagement plans in future collider projects**, across aspects of accelerators, technology, particle physics and detectors
  - Provide a **forum to synergize efforts** on future colliders/accelerators across frontiers
  - **Develop a roadmap** for further (design) studies and R&D for future colliders
  - Work with US universities and other US national labs, and with international collaborators on pertinent issues and proposals
  - **In the past year, the focus was to produce robust input for Snowmass.**
- Recent Activities:
  - Snowmass Agora series on future colliders (5 events, Dec.'21- Apr. '22)
  - Organized mini-workshops (e.g., C^3)
  - Collaborated/co-authored several Future Colliders whitepapers for Snowmass
  - Produced a comprehensive summary of "Future Collider Options for the U.S." https://arxiv.org/abs/2203.08088/
  - Proposed a national R&D program "U.S. National Accelerator R&D Program on Future Colliders" https://arxiv.org/abs/2207.06213

FUTURE COLLIDERS GROUP
(P. Bhat, Head)
(S. Jindariani, Deputy Head)

(A. Bross, ND)	(P. Merkel)
(J. Butler)	(S. Posen, APSTD)
(A. Canepa)	(S. Nagaitsev, DO)
(D. Elvira, SCD)	(S. Belomestnykh, APSTD)
(G. Apollinari, APSTD)	(T. Sen, AD)
(M. Syphers, AD, JA/NIU)	(V. Shiltsev, AD)
(P. Fox, Theory)	(Z. Gecse)

Next Steps in the US

P5 is currently being empaneled

- Expect that discussions will be held with each of the major identified machine concepts
- Key outcome for the US accelerator community will be the ability to re-engage with integrated accelerator development towards collider capabilities
  - Proposal: "U.S. National Accelerator R&D Program on Future Colliders" https://arxiv.org/abs/2207.06213
  - Will need to make the case that the current science/technology focus of GARD is not sufficient for the future of the field
- P5 recommendations will appear next year
  - Hopefully in time to support some changes in US FY2024 (begins Oct 1, 2023)
  - Expect more complete implementation in US FY2025

Will need to coordinate closely with DOE-HEP to re-establish an integrated collider R&D program

New DOE-SC AD for HEP: ***Gina Rameika***

Questions/Challenges

US Energy Frontier program envisions

- Near-Term: Full engagement with the HL-LHC program
  - Mid-Term: Followed by a Higgs Factory
    - Long-Term: An Energy Frontier Collider

Preliminary cost ranges significantly exceed the scale of current US projects

- How do these options interact (compete) with US efforts on the other Frontiers?

US engagement will be limited unless we can have funding directed towards the MC option

- What is a viable model to support US engagement? (Both for the machine as well as the physics/detector efforts)
- Must make a strong case with P5

Conclusion

The MC option was well-received as a potential Energy Frontier option during Snowmass

- Implementing a US Accelerator R&D Program for Future Colliders would provide a mechanism to:
  - Let US accelerator experts engage with ongoing MC development activities
  - Formally participate in the IMCC
  - Explore potential options for US siting
- Developing critical elements of the design between now and the next Snowmass (and European Strategy Update) is crucial!

Thank you for your attention!