Snowmass 2021
EF09 - BSM

More general explorations

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https://snowmass21.org/energy/bsm_general

July 22nd 2020
Energy Frontier Workshop

EF09 - BSM: General exploration

SNOWMASS-EF-09-BSM_GENERIC@FNAL.GOV
Twiki
Indico
Slack: ef09-bsm-generic

- This topical group aims to study the sensitivity of Beyond Standard Model (BSM) phenomena for future experiments in the energy frontier.
  - Particular emphasis is given to signatures that appear in a large variety of BSM extensions.

Mailing-list	SNOWMASS-EF-09-BSM_GENERIC@FNAL.GOV (instructions)
Slack channel	ef09-bsm_generic (instructions)
Next Event	July 20th-22nd, EF workshop: Open Questions & New Ideas, minutes
Expression of Interests (EOI) form	https://forms.gle/1freqMHfTjAobga86
Current EOI	List of Active Proposals agreed to share, comments welcome

EF09 - BSM: General exploration

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- This topical group aims to study the sensitivity of Beyond Standard Model (BSM) phenomena for future experiments in the energy frontier.
  - Particular emphasis is given to signatures that appear in a large variety of BSM extensions.
- 58 Expression-of-interest from individuals/groups aiming for Snowmass studies!
  - useful for initial organization; encouraged to submit a 2-page Letter-of-interests as well
- Topical meetings (~40-100 participants / meeting), typically Fridays @ 11 AM US Eastern time:
  - May 8th 12pm (noon) ET, 2020, kick-off meeting (indico page), minutes
  - May 21st 8am ET, General Energy Frontier Kick-off Meeting (indico page)
  - May 29th 12pm (noon) ET, Heavy bosons (indico page) , minutes, recording
  - Jun 12th 12pm (noon) ET, General LLPs (indico page) , minutes, recording
  - June 26th 11am ET, New Fermions & Exotica (indico page), minutes, recording
  - **July 7th-8th**, Preparatory joint topical group meeting, minutes, recording
  - **July 15th-16th**, Dark Sector and Light Long-Lived Particles, minutes, recording

EF09: Focus Questions

representative,
not comprehensive.
more input welcome!

- Are there new interactions or new particles around or above the electroweak scale? To what extent can future experiments and colliders probe this ?
- Long-lived and feebly-interacting particles represent an alternative paradigm with respect to traditional BSM searches. To what extent can future detectors and accelerators probe such particles ?
- How do we conduct searches in a more model-independent way ?
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- Is lepton flavor universality violated ? What do we learn from high energy/p_T searches ?

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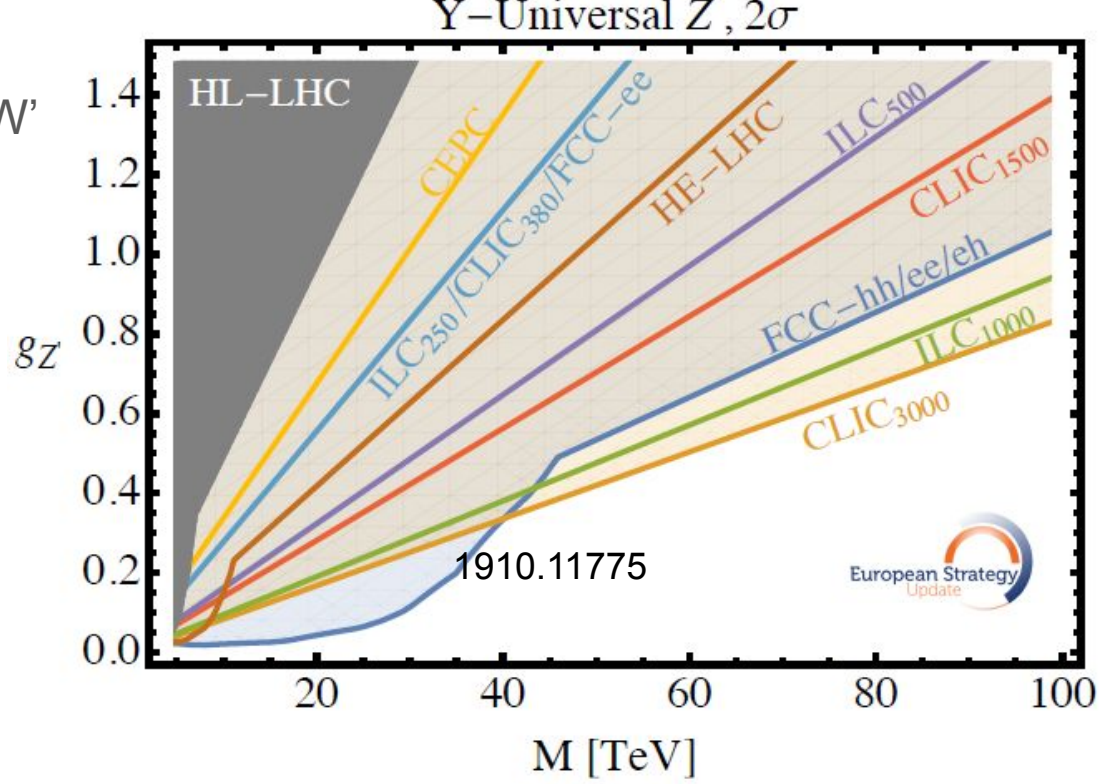
New Resonances

- W'/Z' (leptonic) searches
- Leptophobic scenarios (Z'→tt, W'→tb, …)
- Diboson resonance searches
- Searches with 3rd generation particles (Z' → tau tau)
- Excited quarks/leptons
- Top partners (e.g. Vector-like quarks)
- ….

Rich future programs

- Resonance v.s. Precision
- Rich phenomenology
- Many different channels



New Resonances: open questions

- Proposed colliders extend significantly the reach for heavy resonances
  - Includes characterization of the resonances and the ability to differentiate between models
  - Hadron and lepton machines are complementary
  - Overview talks during the May 29th EF09 meeting
- Detailed studies w/ full simulation/reconstruction would be useful for validating performance
- Open questions to address including how to:
  - fully exploit boosted topologies (e.g. VLQ topologies not much studied at 100 TeV)
    - develop state-of-the-art W/top/Higgs taggers
    - Study impact of detector choices: e.g. calorimeter granularity, tracking
  - Improve high p_T b-jet tagging (also boosted b-jet tagging)
  - Better optimize/study tau final states
  - Better estimation of systematic effects, broader set of models w/ diff couplings to generations, lepton/quark…

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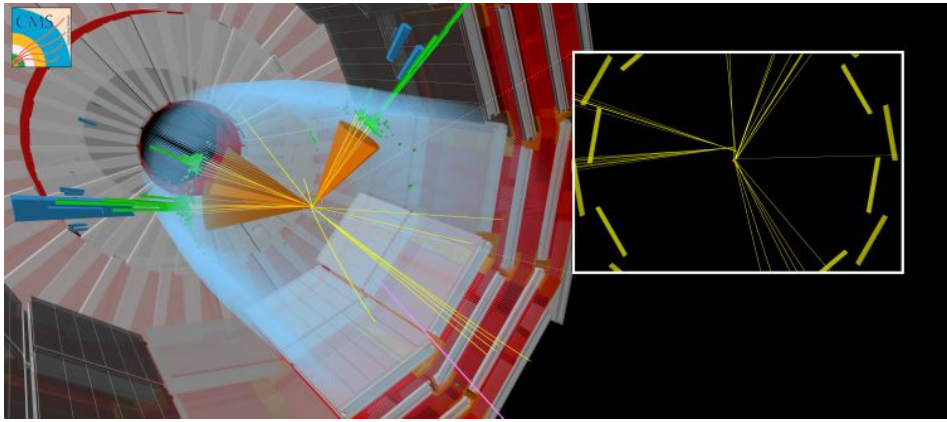
Long-lived Particles (LLPs)

arXiv:1912.12238



Diverse and active area of interest!

- Many signature-driven searches, depending among other things on:
  - Charge: +-1, neutral, multiply-charged, fractional, m/μ-charged,..
  - Lifetime compared to experiment size
  - “Peculiar” properties, e.g. “monopoles”, quirks, ...
- Massive LLPs highlight the potential to look where we could not look before
  - using upgraded HL-LHC detectors (e.g. timing detectors, tracker upgrades), future colliders
  - see May 12th EF09 meeting, Preparatory joint meeting and yesterday’s BSM parallel session
- Light LLPs have been the focus of the Physics Beyond Colliders initiative
  - many new important directions can be pursued during Snowmass
  - see Maxim Pospelov’s talk during the Cross-Frontier meeting on Light LLPs

Long-lived particles: Open Questions

See talks by Juliette Alimena, Nishita Desai, Jonathan Feng, Chris Hill, Simon Knapen & Brian Shuve

- LLP searches have strong interplay with detector design!
  - Of the uncovered (or less well-covered) signatures, which ones are most demanding in terms of new technologies or experiments needed?
  - how can we take advantage and/or shape future development in detector technology?
  - how to reasonably approach projection for detectors at early stage of design?
- How do we compare future collider options ?
  - What are “must-have” LLP signatures (e.g.. HSCP, disappearing tracks, displaced vertices…) ?
  - Can we compile a short list of benchmark models ?
  - And then test sensitivity to LLP signatures ? For varying assumptions of detector performance ?
- How do we achieve comprehensive coverage with existing accelerator facilities ?
  - Build on and extend the LLP white paper: arXiv 1903.04497
  - Better exploit upgraded HL-LHC detectors, advanced techniques, new trigger strategies...
  - Exploit the full potential of auxiliary experiments (FASER, milliQan, MATHUSLA, MOEDAL,...)
  - Explore novel forward facilities/detectors with unique physics cases for LLPs...

Synergy with Instrumentation Frontier, Accelerator Frontier & Rare Processes Frontier

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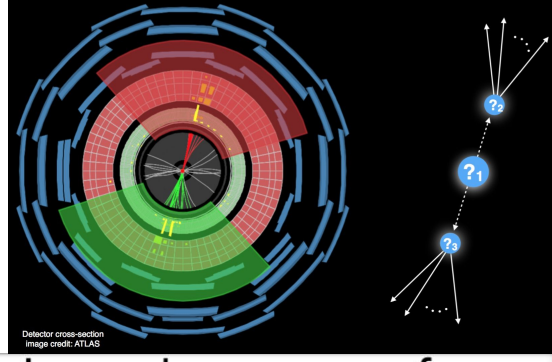
Model-agnostic searches

- Ensure widest potential for discovery is probed
  - qualitative differences for lepton vs hadron colliders
- Might be useful to survey existing and future (R&D) methods
  - explore machine learning methods ?
- Interplay with detector design
  - ensure emerging physics ideas are not severely limited by “arbitrary” design choices but can exploit in full each accelerator’s potential

Synergy with Theory Frontier & Computational Frontier

https://lhco2020.github.io/homepage/



KC Kong

Unexplored Landscape of Two-Body Resonances

( ): boson resonance

[ ]: fermionic resonance

∗: no possible initial state at the LHC

♢ $\Delta B = 1$

♡ $\Delta L = 1$ (if couples to q / g)

Possible (QCD, EM) quantum numbers of each 2-body resonance

indicates the existence of a resonant production via tree-level decay coupling, loop-induced processes involving the decay coupling, or the inclusion of additional couplings to quarks / gluons (allowed by quantum numbers).

, , , or indicate the leading production mode in association with 1, 2, 3 and 4 SM particles using the same coupling for production and decay (in 4 flavor scheme).

indicates the unavoidable existence of a pair production mode.

Craig, Draper, Kong, Ng, Whiteson 1610.09392

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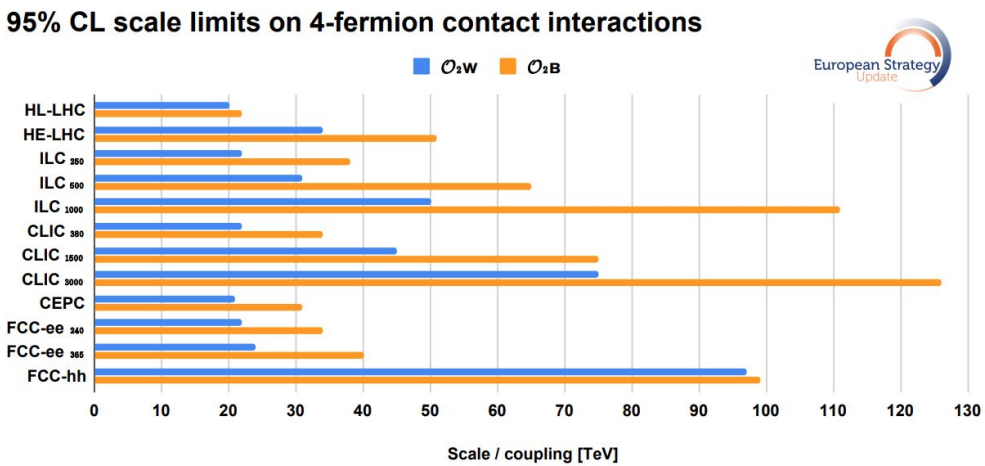
Open Questions

- How do we compare the results of different experiments in a more model-independent way to ensure complementarity and avoid gap in coverage?
  - Reinterpretations ? Use carefully chosen simplified models ? [See yesterday's discussion.]
  - Explore BSM effects via global EFT fits ? [w/ EF04]



Providing answers to the above focus question is an important goal for the EF Snowmass studies;

Includes collaboration with other Frontiers in some cases

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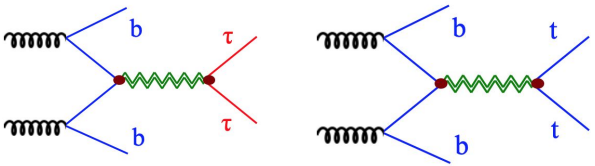
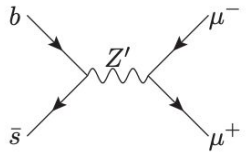
Lepton flavor universality: high-p_T searches

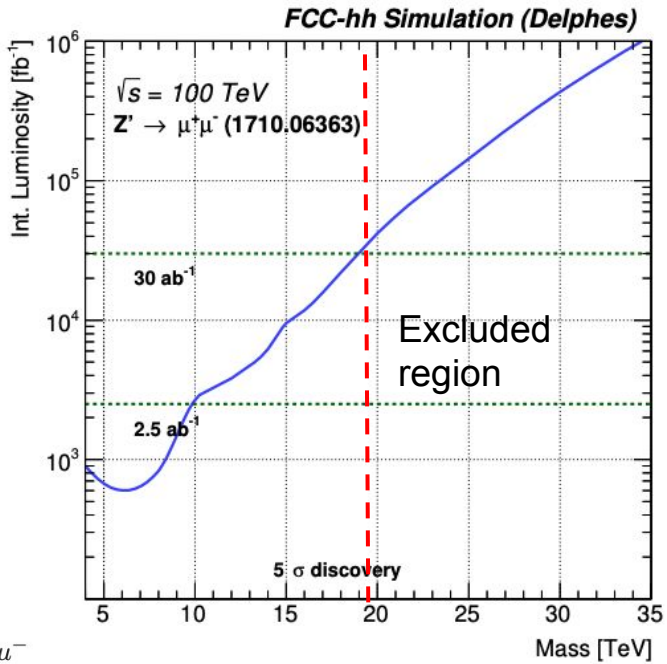
https://arxiv.org/pdf/1902.11217.pdf

- Top quark FCNC effects (EF03)
- Leptoquarks (EF08)
- Explore searches looking for large deviations in tau tau (w/o narrow peak) and ttbar final states



- Flavor anomaly inspired Z' models
  - studies done using model where Z' only couples to b/s quarks (g_{sb}) and to muons ($g_{\mu\mu}$).
  - Additional studies (w/ different model assumptions) are very welcome!





Full allowed mass range can be explored

Conclusions

- Goal to sample a vast and rich physics program for BSM physics at future energy-frontier experiments
  - can't be comprehensive, instead aim to give a flavor of the richness of the program and try to communicate complementarity of different search strategies and reach
  - ranging from "standard candles" (q*, l*, Z', T, ..) to more exotic models (dark-sector, ALPs, …)
- We're still in the initial phase of collecting input and interest, invite people to form new collaborations for specific studies.
  - … and no, it's not too late by any means to get engaged! Submit your EoI or LoI!
- Large interplay with other EF groups and frontiers yielding to combined meetings and mini-workshops
  - ultimately need to ensure results can be used in the report as they best fit without the need of large last-minute modifications or too-rough assumptions
  - Interplay with detector technology to ensure we're well equipped to find the the BSM physics that Nature has chosen!