Summary of Snowmass 2014 Physics Studies: at 100 TeV and Plans: want do we do next?

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VLHC

- From the perspective of BSM, a likely interpretation of the Higgs is that the relevant scale may be higher than that accessible to the LHC.
- Deeper understanding of flavor & other fundamental issues requires a very high energy collider.
- The ~100 TeV collider is expected to explore a well-motivated energy region (after discoveries with LHC upgrade)
  - not meant to push new-physics limits by an order of magnitude

- From the Snowmass New Particles Report Summary:
- "A 100 TeV pp collider has unprecedented and robust reach for new physics that is evident even with the preliminary level of studies performed so far. It can probe an additional two orders of magnitude in fine-tuning in supersymmetry compared to LHC14, and can discover WIMP dark matter up to the TeV mass scale. Any discovery at the LHC would be accessible at this machine and could be better studied there, making the case for these options even more compelling."

New Particle Reaches

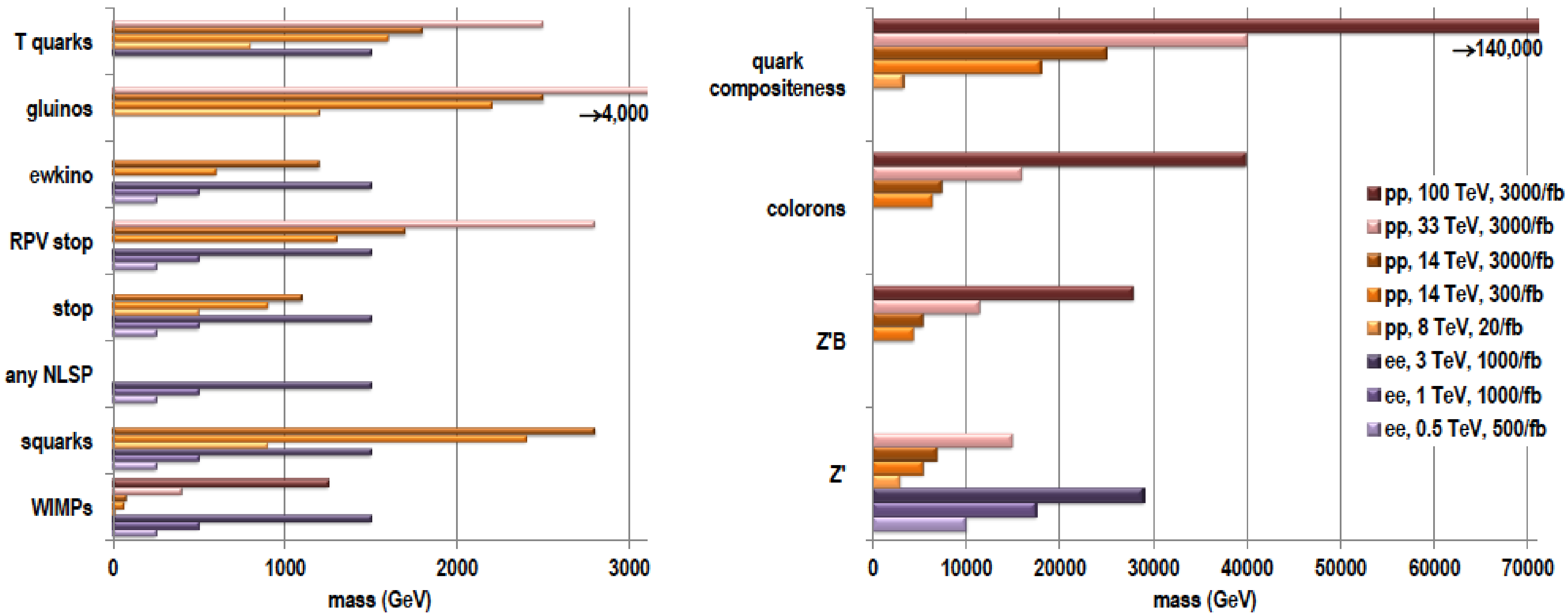

Figure 22-1. *95% confidence level upper limits for masses of new particles beyond the standard model expected from pp and e^+e^- colliders at different energies. Although upper mass reach is generally higher at pp colliders, these searches often have low-mass loopholes, while e^+e^- collider searches are remarkably free of such loopholes.*

Snowmass Exec Summary: VLHC

http://www-public.slac.stanford.edu/snowmass2013/docs/Energy-3.pdf

- VHLC, at 100 TeV
- One of the ideas that gained momentum at Snowmass was renewed interest in a Very Large Hadron Collider (VLHC). Our study recommends reinvigorating R&D toward realization of a VLHC. A VLHC will:

1. Provide high rates for double Higgs boson production, and a measurement of Higgs boson self coupling to 8%.
2. Search sensitively for new Higgs bosons and states associated with extended Higgs sectors at 1 TeV.
3. Dramatically improve the sensitivity to vector boson scattering and multiple vector boson production.
4. Increase the search reach for new particles associated with naturalness - including SUSY particles, top partners, and resonances - by almost an order of magnitude in mass over LHC. This corresponds to two orders of magnitude in fine-tuning.
5. Search for WIMP dark matter up to TeV masses, possibly covering the full natural mass range.
6. Follow up any discovery at LHC = or in dark matter or flavor searches - with more detailed measurements, and with searches for related higher-mass particles. Both luminosity and energy are relevant.

Snowmass Exec Summary: VLHC

- We have emphasized that the quest to understand the TeV scale will not be finished with the results of accelerators of the next generation. It is likely that the discovery of new particles at the next stage of collider physics will open a definite path for exploration to still higher energies. Our study called attention, in particular, to the capabilities of a VLHC for further exploration of the TeV mass scale. The journey to still higher energies begins with renewed effort to bring advanced accelerator technologies to reality.

Snowmass studies @ LPC including @ 100 TeV

- arXiv:1309.1057: Snowmass Energy Frontier Simulations
  - (Jacob Anderson, Aram Avetisyan, Nitish Dhingra, James Dolen, James Hirschauer, Sudhir Malik, Patricia Mcbride, Kalanand Mishra, Meenakshi Narain, Jim Olsen, Sanjay Padhi, Michael E. Peskin, John Stupak et al
- arXiv:1308.1636: Methods and Results for Standard Model Event Generation at \sqrt{s} = 14 TeV, 33 TeV and 100 TeV Proton Colliders
  - Aram Avetisyan, John M. Campbell, Timothy Cohen, Nitish Dhingra, James Hirschauer, Kiel Howe, Sudhir Malik, Meenakshi Narain, Sanjay Padhi, Michael E. Peskin, John Stupak, Jay G. Wacker
- arXiv:1308.0843: Snowmass Energy Frontier Simulations using the Open Science Grid
  - A. Avetisyan (1), S. Bhattacharya (2), M. Narain (2), S. Padhi (3), J. Hirschauer (4), T. Levshina (4), P. McBride (4), C. Sehgal (4), M. Slyz (4), M. Rynge (5), S. Malik (6), J. Stupak III (7),

- SUSY, Exotica Higgs
- arXiv:1311.6480:SUSY Simplified Models at 14, 33, and 100 TeV Proton Collider , (S. Padhi et al)
- arXiv:1310.0077: A Comparison of Future Proton Colliders Using SUSY Simplified Models (S. Padhi et al)
- arXiv:1309.7342 Electroweakino Searches: A Comparative Study for LHC and ILC (S. Padhi et al)
- arXiv:1309.5966: Electroweakinos in the Light of the Higgs Boson (S. Padhi et al)
- arXiv:1309.2234 Search for top partners with charge 5e/3 (Aram Avetisyan, Tulika Bose)
- arXiv:1308.6334: Heavy Higgs Scalars at Future Hadron Colliders,
  - Eric Brownson, Nathaniel Craig, Ulrich Heintz, Gena Kukartsev, Meenakshi Narain, Neeti Parashar, John Stupak
- arXiv:1308.3903: Sensitivity of an Upgraded LHC to R-Parity Violating Signatures of the MSSM (James Hirschauer et al).
- arXiv:1309.0026: Prospects for a Heavy Vector-Like Charge 2/3 Quark T search at the LHC with \sqrt{s}=14 TeV and 33 TeV.
  - (Saptaparna Bhattacharya, Jimin George, Ulrich Heintz, Ashish Kumar, Meenakshi Narain, John Stupak)
- arXiv:1309.7684: Discovery potential for heavy t-tbar resonances in dilepton+jets final states
  - (Ia Iashvili, Supriya Jain, Avto Kharchilava, Harrison B. Prosper)

What next? Some ideas…

- “springboards for discussion”
- 100 TeV samples for snowmass are with a given Delphes version and "snowmass combined detector" arXiv:1309.1057
  - "fake" PU jets can be reduced, efficient sub-jet studies due to eta dependent rho corrections
  - Also need to retune the "isolation cones for the leptons?
- extend simulations
  - The detector technologies are expected to evolve e.g EFCA digital calorimeter, better silicon detector, large pseudo rapidity coverage etc.
  - We may need to "re-create" new detector geometry with "best available" knowledge
  - Advantages: Better PU mitigation, large eta coverage for VBF, better segmentation and efficiencies for boosted physics
  - ?? jets, Missing ET resolutions, b-tagging, improved Jet substructure tools/techniques
  - Can be used globally?

springboards for discussion

- extend SM background statistics?
  - updated simulations and detector design
    - re-negotiate with OSG for computing cycles?
    - revamp the production scripts
    - resource management (volunteer personnel?)
- work on understanding
  - PDFs in new a domain of (x,Q)? structure of UE? MC? detector technology
- Physics: define benchmark processes for signals?
- Detectors: think of enabling technologies than developing devices for particular tasks?
  - Extrapolation from present techniques may not be the path to take – “Think outside the box”
- continue meeting once a month, working towards a July 28-31 workshop?