1 100 TeV Colliders

1.1 Keynotes

- Key note talks in FCC week 2015 by Benedikt [7] and Schulte [6].
- Preliminary CDR [1].

Machine design, luminosity and cross section

- Barletta–Battaglia+ [3] for a review of accelerator physics for future colliders.
- Assadi–Collins+ [31] for overview and cost estimate.
- Richter [46] (also Barletta–Battaglia+ [3]) reminded us that $\sigma \propto E^{-2}$ (or s^{-1}) and pointed out that the luminosity goal should be set as $(100/14)^2 \times$ (LHC value) in order to maintain the discovery potential, and to get funded. Because of the Lorentz contraction the luminosity is expected to scale as $\propto s$, this claim for $15\,\mathrm{ab}^{-1}$ ($= 300\,\mathrm{fb}$@LHC) is fairly reasonable.
- Based on the discussion, Hinchliffe–Kotwal+ [65] also calls for an integrated luminosity of 10–$20\,\mathrm{ab}^{-1}$ with showing the cross sections for several processes, but "have not found generic arguments to justify them."
- Rizzo [59] studies cross section scaling. Naive estimation gives σ scales as $E^2\sigma(m,E) = E_0^2\sigma(m\frac{E_0}{E}, E_0)$, but because of PDF evolution and α_s running, σ at higher energy drops more rapidly, especially for process involving gluon PDF ($\sim -50\%$) or more QCD-couplings ($\sim -15\%$ for each).

1.2 Phenomenology

Snowmass 2013

- Avetisyan–Campbell+ [19] provides Snowmass SM Background set, the detector simulation for which is explained in Anderson–Avetisyan+ [22]. See also the talks in SLAC (2014): Selvaggi [5] and Hirschauer [4].
- $t\bar{t}$ charge asymmetry in Berge–Westhoff [16].
- q-compositeness (jj angular dist.) in Apanasevich–Upadhyay+ [17].
- hh in Yao [20]: $bb\gamma\gamma$ channel is utilized to measure HSC at 8% (stat only). This is included in Higgs WG report, Dawson–Gritsan+ [27].
- $\tilde{q}$ and $\tilde{g}$ in Cohen–Golling+ [26], extended in Cohen–Golling+ [28]: see "SUSY" below.
- Warped XD in Agashe–Antipin+ [25] but at 33 TeV. $Z' \to t_\mathrm{h}t_\mathrm{h}$, $G^{(1)} \to Z_\mu Z_j$, $g^{(1)} \to t_\mathrm{h}t_\mathrm{l}$, and KK $Z/W/\gamma$ are thoroughly studied.
- jj resonance in Yu [18] (singlet Z' & octet G') and Anderson [21] (q^*).
- Z' in Godfrey–Martin [23] (20–30 TeV).
- Vector-like top quarks in Andeen–Bernard+ [24].

General

- Larkoski–Thaler [38] examines jet physics: winner-take-all aces, soft drop clustering, and Sudakov-safe observables. The first two works very well to remove contaminations from pile-up etc.
- Hook–Katz [39] investigates W- and Z-radiation from $E \gtrsim 1\,\mathrm{TeV}$ particles, which can be utilized to see ν (or to determine $\not{p}$), to determine SU(2) charge of new particles, and in the decay of heavy scalar whose 3-body decays are enhanced.

SUSY

For colored SUSY particles pair-production (production crosssections in Borschensky–Krmer+ [41]),

- $\tilde{q}$ and $\tilde{g}$ in Cohen–Golling+ [28]: $\tilde{g}\tilde{g}(\tilde{q}\tilde{q}) \to 4q(2q) + \not{E}_{\mathrm{T}}$ (both of splitted and degenerate), $\tilde{q}\tilde{q}+\tilde{q}\tilde{g}+\tilde{g}\tilde{g}$ with massless $\tilde{\chi}^0_1$, and $\tilde{g}\tilde{g} \to 4t + \not{E}_{\mathrm{T}}$ are studied. CMSSM interpretation is found in Fowlie–Raidal [30] and Fowlie [33].
- Jung–Wells [29] studies Split-SUSY ($\mathcal{O}(1)$ TeV inos while decoupled sfermions) motivated by DM and m_h ($m_{\tilde{q}} \lesssim 100\,\mathrm{TeV}$). Signal is $2^+j0l\not{E}_{\mathrm{T}}$ from $\tilde{g} \to \tilde{w}\bar{q}q$ pair; AMSB, GMSB, and mirage are in scope. They say the thermal wino LSP cannot be covered even with $10\,\mathrm{ab}^{-1}$.
- Beauchesne–Earl–Gregoire [62] also studies (mini-) Split-SUSY based on GMSB and (deflected) AMSB; $\tilde{g}$ decays into t and b, i.e., $2^+b0l\not{E}_{\mathrm{T}}$ and $2^+l^{\mathrm{SS}}8^+j(2^+b)\not{E}_{\mathrm{T}}$ are considered. Thermal wino LSP region is not fully covered.
- Ellis–Zheng [71] analyzes $\tilde{q}$+gaugino production, where $\tilde{q}$ of 30 TeV ($\tilde{g}$, 8 TeV), 14 TeV ($\tilde{W}$, 4 TeV), and 9 TeV ($\tilde{B}$, 2–3 TeV) are within the reach of exclusion. They also pointed out that gluino–neutralino DM coannihilation region can be excluded for $\tilde{q} < 32\,\mathrm{TeV}$.
- Cohen–D'Agnolo+ [37] analyzes $\tilde{t}\tilde{t} \to tt + \not{E}_{\mathrm{T}}$. With a large mass splitting (boosted top), a μ in either of the leading $2j$ is required. Compressed spectra are also studied.

For non-colored SUSY particle pair-production,

- Acharya–Boek+ [47] studies $\tilde{\chi}\tilde{\chi}$ production in $|\mu| < M_2 \ll M_1, m_{\tilde{l}}$ (decoupled) case, $3^{=}l0b + \not{E}_{\mathrm{T}}$ signal.
- Gori–Jung+ [48] is more complete: scenarios with $M_1 \gg M_2\,\&\,\mu$, $M_2 \gg \mu > M_1$ and $\mu \gg M_2 > M_1$ are studied with $3l$, $4l$, SS$2l$ and OS$2l$ signatures. They also mention that in $Z \to ll$ the leptons will be reconstructed as a single jet to degrade the searches.
- Cortona [55] extrapolates LHC results to obtain constraints at 100 TeV (no MC simulation), including $\tilde{W}\tilde{H} \to Wh(\to b\bar{b})$ and disappearing $\tilde{W}$ signatures. DM interplay in models with split-SUSY, AMSB and GMSB are also studied.
- Bramante–Fox+ [53] studies $\tilde{\chi}^{0,\pm}$ searches motivated by the M_1–M_2–μ surface to explain Ω_{DM}.

Exotic signals (also see the section "Exotics"),

- Low–Wang [35] discusses SUSY DM searches: mono-jet (pure $\tilde{W}/\tilde{H}$, $\tilde{B}$-coann. with $\tilde{g}$, $\tilde{t}$, $\tilde{q}$), disappearing track (pure $\tilde{W}/\tilde{H}$), and soft leptons ($\tilde{B}$–$\tilde{W}$–$\tilde{H}$ mixed).
- Cirelli–Sala–Taoso [42] is an extension work, which focuses on $\tilde{W}$-like DM and additionally considers mono-γ, VBF $2j_{\mathrm{forward}} + \not{E}_{\mathrm{T}}$.
- Berlin–Lin+ [61] also studies VBF $2j_{\mathrm{forward}} + \not{E}_{\mathrm{T}}$, which perfomrs matching for additional jets, and considers $\tilde{H}$ case as well.

- Arbey–Battaglia–Mahmoudi [70] is also on mono-jet searches; not citing the previous papers.

Also,

- Ellis–Kane–Zheng [44] studies G_2-MSSM, predicting $m_{\tilde{g}} = 1$–$2\,\mathrm{TeV}$ and $m_{\tilde{q}} \sim 20\,\mathrm{TeV}$, in $\tilde{g}\tilde{g}$, $\tilde{t}\tilde{g}$, $\tilde{b}\tilde{g}$ and $\tilde{\chi}\tilde{\chi}$ productions, but only the crosssections are shown.

Extra dimension

- Chen–Davoudiasl–Kim [32] studies RS warped $G^{(1)} \to Z_{ll}Z_{\nu\nu}$.
- Agashe–Chen+ [56] studies RS warped $G^{(1)} \to \gamma_1\gamma \to W_jW_l\gamma$

Z' and W'

- Earlier works for 100–200 TeV pp colliders are Rizzo [8] and Godfrey [9].
- Rizzo [34] provides much more realistic analysis, focusing on electron final states (because of worse momentum resolution of μ). Coupling determination is discussed, and the importance of the three body decay (studied as early as in Cvetic–Langacker [2][*1]) is also referred.

SM and Higgs sector

- Wen–Qu+ [40] looks for WWW production to see anomalous QGC (W^4 coupling).
- Alves–Galloway+ [49] studies $\alpha_{1,2}(Q)$ measurement by DY ll and $l\nu$ processes.
- Di-Higgs production
  - Baglio–Djouadi+ [13] (cf. Shao–Li+ [14]) calculates di-Higgs cross section.
  - Chen–Low [36] sees di-Higgs kinematical distributions to constraint $t\bar{t}h$-, h^3- and non-SM $t\bar{t}hh$-couplings.
  - Barr–Dolan+ [57] studies $hh \to bb\gamma\gamma$ and HSC determination, extending Snowmass work Yao [20], to conclude $\lambda/\lambda_{\mathrm{SM}} \in [0.64, 1.45]$ ($[0.89, 1.13]$) at $3\,\mathrm{ab}^{-1}$ ($30\,\mathrm{ab}^{-1}$).
  - Azatov–Contino+ [60] also did it, in EFT language, with a good review of past works.
  - Li–Li+ [63] studies hh production in $4W \to 3l_{\mathrm{SSSF}}2j$ channel; fairly good at 100 TeV.
  - Papaefstathiou [64] studies rare channel of hh production: $b\bar{b}Z_lZ_l$ (less prospective), $b\bar{b}Z_l\gamma$ (impossible), $b\bar{b}+2l$ (from WW and $\tau\tau$ promising, but from $\mu\mu$ impossible for a large BKG).
- He–Li–Zheng [58] tries to determine tth-coupling (strength and CP-structure) in $t\bar{t}h$ ($\to b\bar{b}$ and $\gamma\gamma$) but detector effects are not considered; theoretical analysis.

Exotics

- Zhou–Berge+ [15] studies mono-jet signature motivated by DM scenarios, based on EFT D5/8/9 and Z' on-shell mediator.
- Curtin–Meade–Yu [45] considers EW baryogenesis with strong first-order EWPT, achieved with single $\mathbb{Z}_2$-odd singlet scalar, which can be constrained by HSC measurement or VBF production $h \to SS$, as well as searches at TLEP.
- Craig–Lou+ [52] also studies the model; $j + \not{E}_{\mathrm{T}}$, $t\bar{t} + \not{E}_{\mathrm{T}}$, and VBF $2j_{\mathrm{forward}} + \not{E}_{\mathrm{T}}$ ($\not{E}_{\mathrm{T}}$ from $h \to SS$) are considered.

[*1] Further readings are Ciafaloni–Comelli [10], Baur [11] and Bell–Kuhn–Rittinger [12].

- Feng–Iwamoto+ [68] studies the reach of long-lived $\tilde{l}$ searches, mentioning the worse momentum resolution at higher p_{T} and the possibility of muon radiative energy loss.
- Khoze–Ro–Spannowsky [69] studies the reach for s-ch. med. DM scenarios (Higgs portal and generalized) in searches for $2j_{\text{forward}} + \not{E}_{\mathrm{T}}$.

Other models

2HDM Auerbach–Chekanov+ [54] studies the reach of $t\bar{t}$-resonance searches with cut-based top tagging.

Hajer–Li+ [66] studies heavy Higgs searches with BDT t-tagging; $bbH/A \to bbtt/\tau\tau$ and $tbH^{\pm} \to tbtb$, and found that moderate $\tan\beta$ region is covered by $2b2t$ signals.

String resonances Anchordoqui–Antoniadis+ [43] studies searches for string resonances in jj and γj signatures.

Majorana neutrino Alva–Han–Ruiz [50] studies VBF $W\gamma \to Nl$, t-ch. enhanced and can be larger than DY $W^* \to Nl$, resulting in SS2l signature. Signal is $2^{=}l^{\mathrm{SS}}2^{+}j$ without $\not{E}_{\mathrm{T}}$. Their MC analysis is detailed and performed carefully.

Dark photon Curtin–Essig+ [51] studies dark-photon γ' searches. With kinetic mixing only, $h \to Z\gamma' \to 4l$ ($m_{\gamma'} = 12$–$62\,\mathrm{GeV}$) and DY $\gamma' \to ll$ (12–90 GeV and 180 GeV–) will exclude $\epsilon \gtrsim 10^{-3}$. With Higgs mixing, $h \to \gamma \to 4l$ ($2m_{\mu}$–$m_h/2$) is considered. Indirect constraints from ILC etc. are also discussed.

Composite Higgs Kotwal–Chekanov–Low [67] studies $\eta \to hh \to 4\tau$ searches, highlighting the 4τ channel as the golden-channel for di-Higgs production; also mentions the difficulty of τ-tagging with $p_{\mathrm{T}} \gtrsim 1\,\mathrm{TeV}$.

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