The Single Top Quark Coupling to the Higgs Potential

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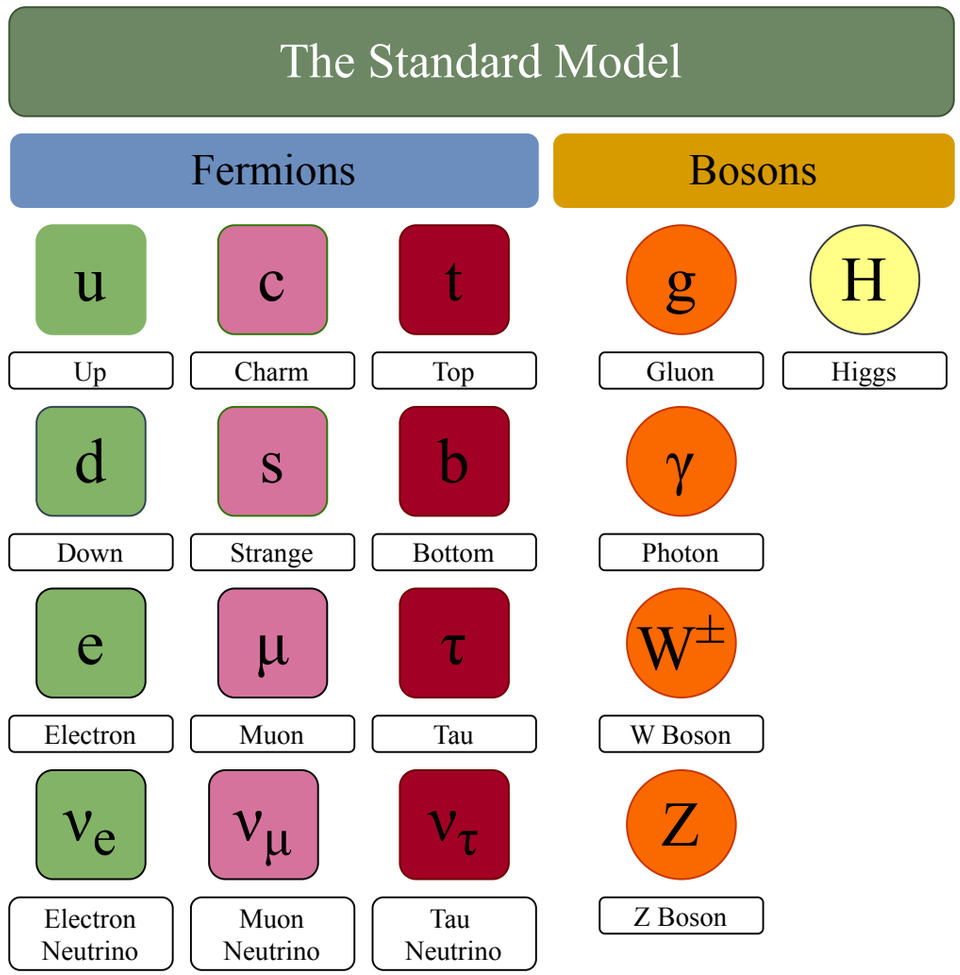
Outline

- Background Physics
- Why the Top quark is of Importance
- The Single Top Quark and its specific uses
- Production and Decay of the Illusive Single Top Quark
- The Coupling to the Higgs Potential
- Current efforts and the plans for the future
- The rewards of our efforts and what impact this could have on the field in the future

Background Particle Physics

- The Standard Model
  - Quark Families
  - The Higgs Boson
- Symmetries
  - Charge Conjugation
  - Parity
- The Yukawa Coupling



The Importance of the Top Quark

- Top Yukawa Coupling Magnitude
  - ElectroWeak Scale
- Limit of Current Experimental Results
- An Indicator for Beyond Standard Model Physics
  - Electroweak Symmetry Breaking
- Single Top Quark Measurements
  - Cross-Section Measurements
  - Phase
  - CP Violation

$$\mathscr{L}_{htt} = -\, g_{htt} h\bar{t}(\cos(\xi_{htt}) + i\sin(\xi_{htt})\gamma_5)t$$

$$g_{htt} = (m_t/v)\kappa_{htt} > 0$$

Minimal non-SM Lagrangian for Yukawa Coupling (g) [1]

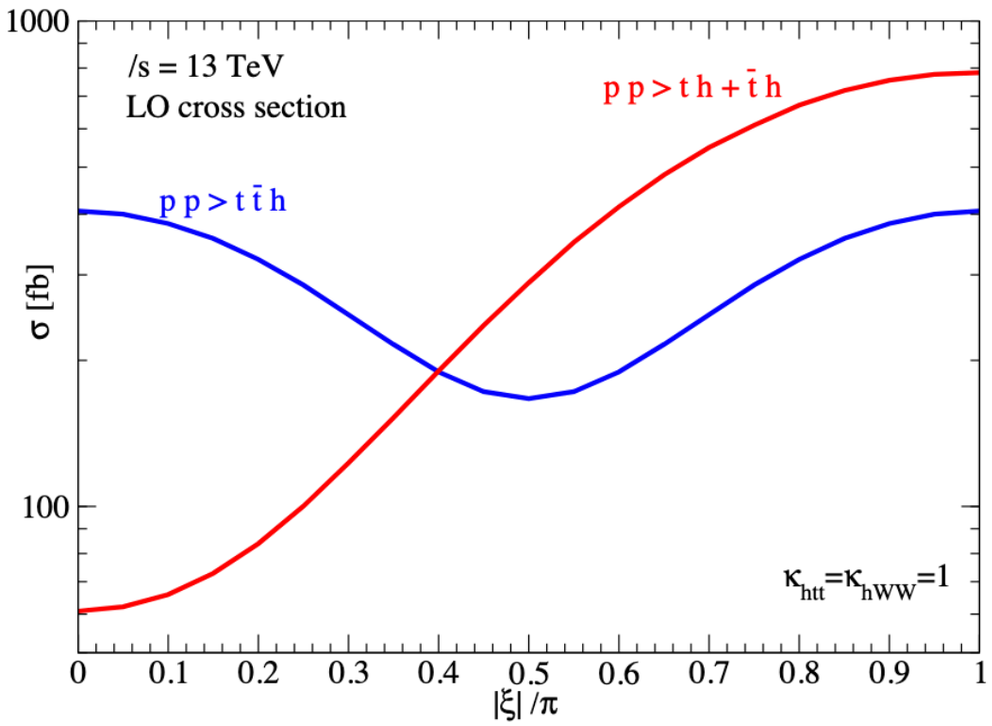


Figure 1: Cross section of tt bar and t Higgs cross sections as a function of phase [1]

The Production and decay of Single Tops

- Productions Channels
  - t-channel
  - s-channel
  - tW production

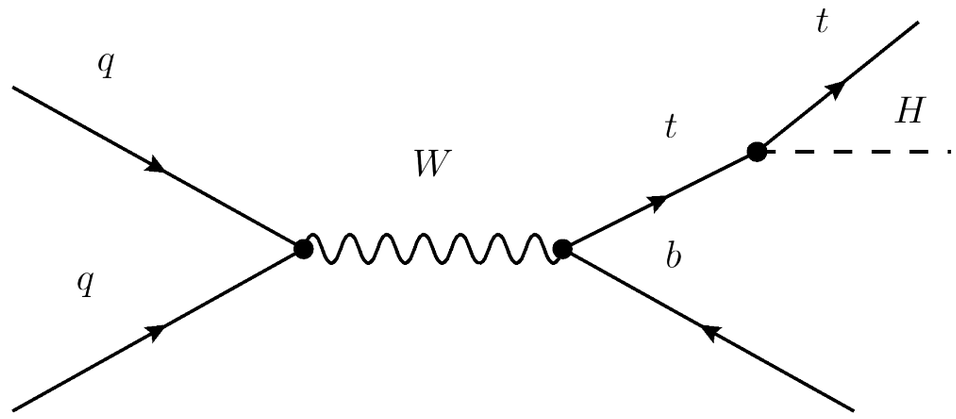


Figure 2: t-channel single top quark production

- Identification of Top Quarks
  - bW Decay — almost always
  - b-tagged Jets
  - Hadronisation or not

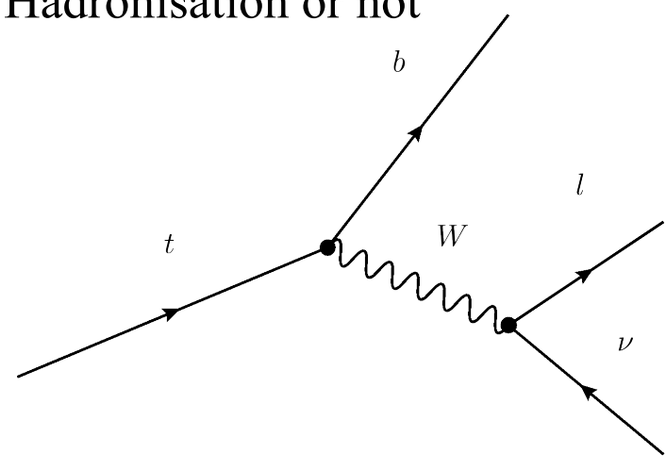


Figure 4: bW decay of top quarks

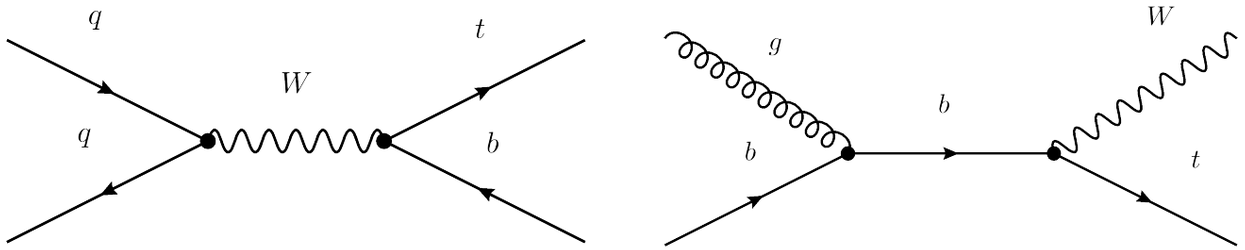


Figure 3: s-channel (left) and tW production (right)

Single Top Higgs Coupling

- Starting from $t\bar{t}h$ coupling
- th and $\bar{t}h$ why have we not detected it
- Why is this important? Phase?

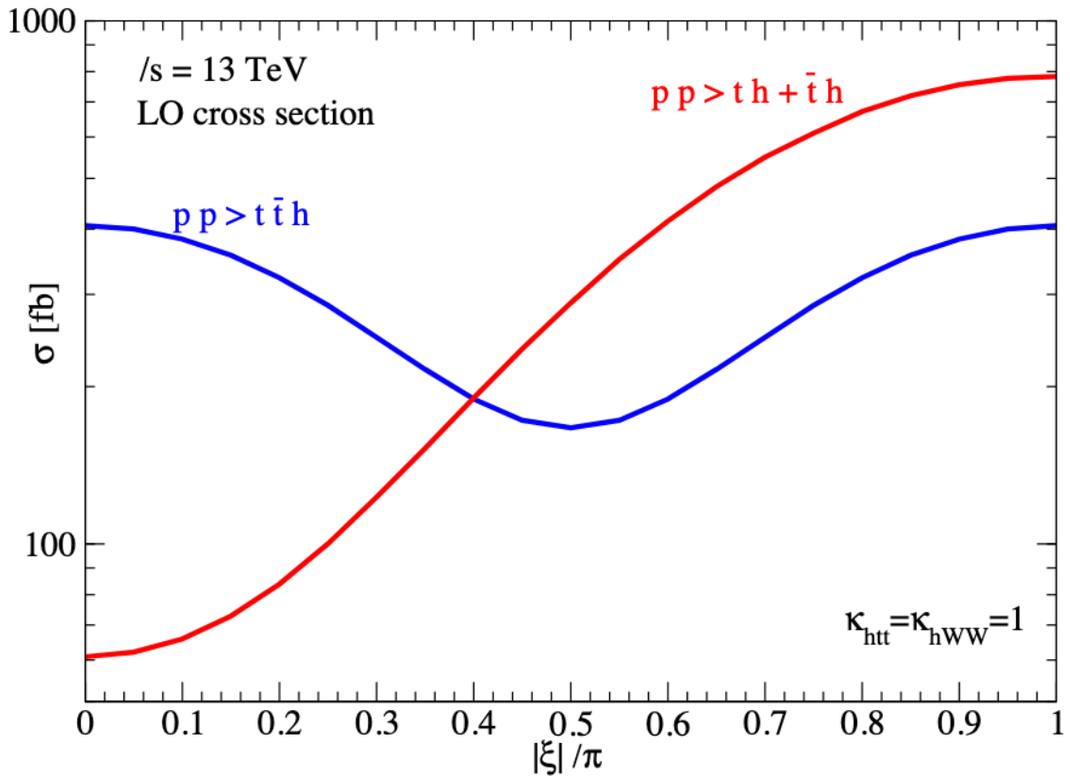


Figure 1: Cross section of tt bar and
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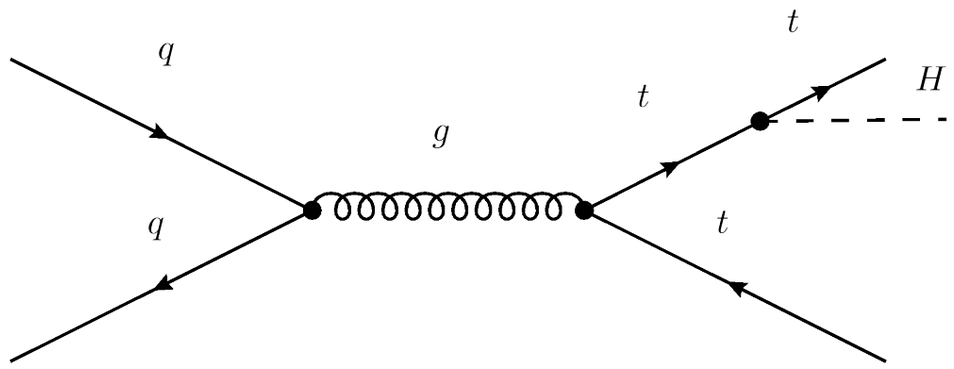

Figure 5: t tbar production from a
quark anti-quark pair

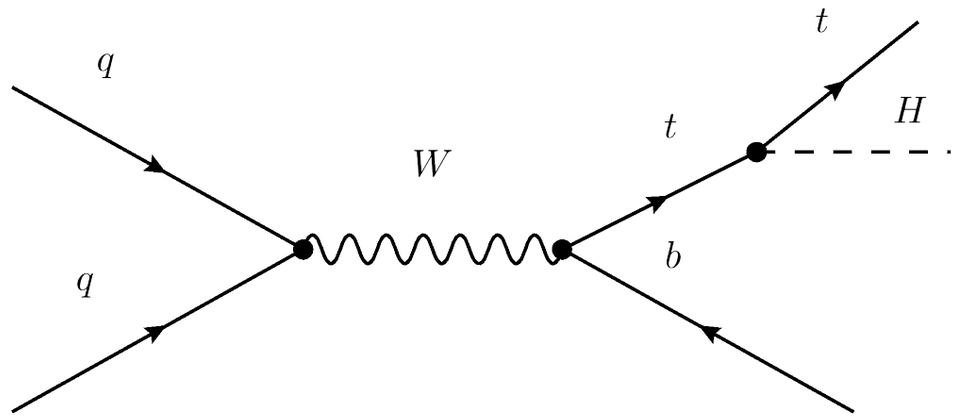

Figure 6: t-channel single top production
with a tH coupling on the resultant top quark

Current Searches and Future Prospects

- Run 1 and 2 Data
- Run 3 Analysis
    - Published results
    - What the entire dataset may tell us
- HL-LHC
    - How does this help
- FCC, do we really need a bigger Collider?

Table 1: Total Energies of Runs at the LHC

	Energy
Run 1	7 & 8 TeV
Run 2	13 TeV
Run 3	13.6 TeV

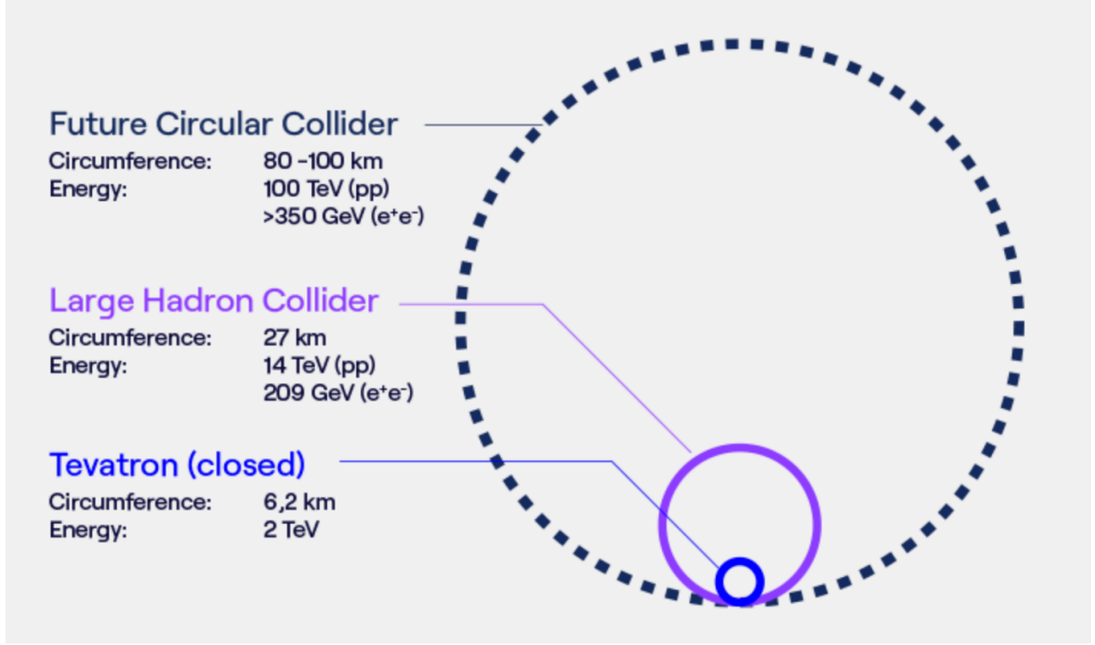

Figure 7: Proposed FCC collider located at Cern [3]

What this Means for BSM Physics

- Returning to CP Violation

- Baryogenesis
    - Matter Anti-Matter Asymmetry
    - Top Quarks Observed in Quark Gluon Plasma

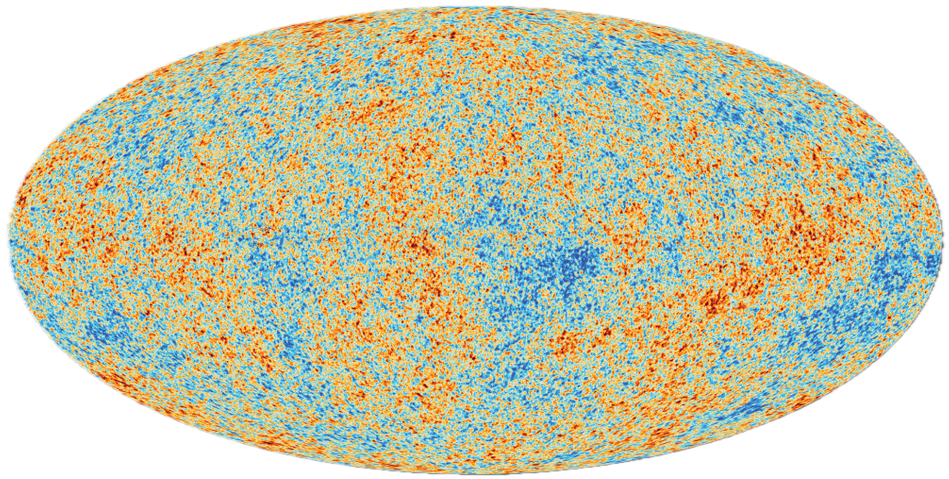

Figure 8: CMBR from Planck Telescope [4]

- A Probe for higher energy physics
    - Beyond the TeV Scale
    - Recombination of the ElectroWeak Symmetry

Summary

- The Yukawa Coupling
- The Top Quark As the current limit of Particle Physics
- Production and why this is difficult
- What we can do in the Future to improve data collection
- How the Top Quark is a leading candidate for BSM Physics

References

[1] Vernon Barger, Kaoru Hagiwara and Ya-Juan Zheng. Probing the top Yukawa coupling at the LHC via associated production single top and Higgs. *Journal of High Energy Physics,* 2020(9):101, September 2020. arXiv:1912.11795 [hep-ph].

[2] Jeremy Andrea and Nicolas Chanon. Single-top quark physics at the LHC: from precision measurements to rare processes and top quark properties. *Universe,* 9(10):439, September 2023. arXiv:2307.14044 [hep-ex].

[3] Cosmic Microwave Background (CMB) Radiation, *https://www.esa.int/Science_Exploration/Space_Science/Cosmic_Microwave_Background_CMB_radiation,* Accessed 2024-11-22

[4] FCC Feasibility Study, *https://fcc.web.cern.ch/overview,* Accessed 2024-11-22

[5] J. Katharina Behr and Alexander Grohsjean. Dark Matter Searches with Top Quarks. *Universe,* 9(1):16 January 2023. Number: 1 Publisher: Multidisciplinary Digital Publishing Institute.