



Observations of the Top Quark

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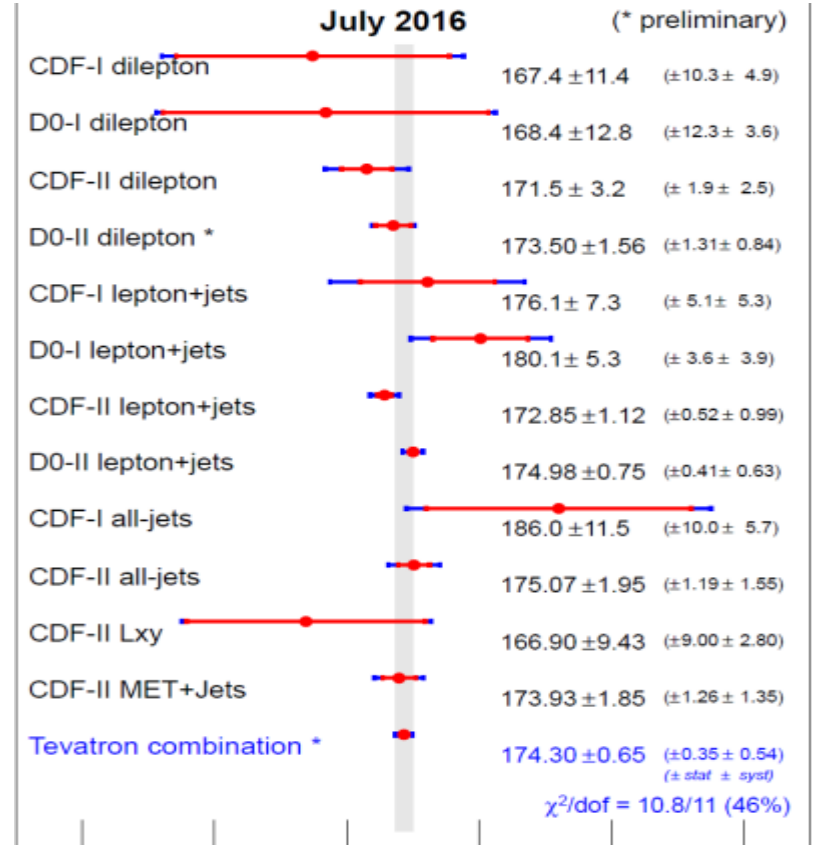
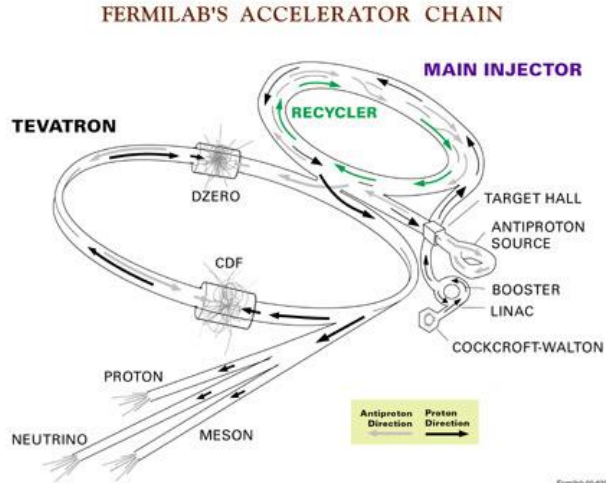
Overview

1. Introduction
 2. Standard Model Review
 3. Top Production and Decay
 4. Methods and Analysis
 5. Results
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Tevatron

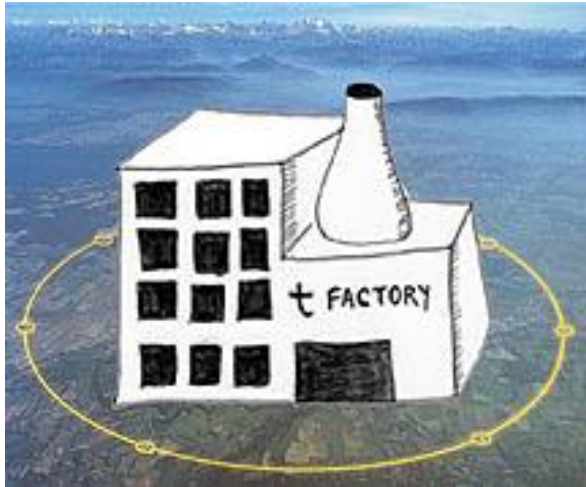
- ❑ Active years: 1983 – 2011
- ❑ Maximum beam energy: ~1TeV
- ❑ Collision type: proton/anti-proton
- ❑ CDF and D-Zero experiments
- ❑ Main achievement – top quark discovery 1995
- ❑ Tevatron measured mass 174.30 ± 0.65 GeV





Large Hadron Collider (LHC)

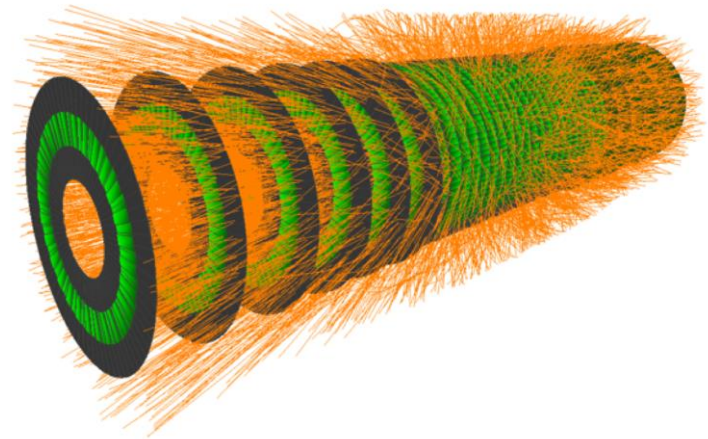
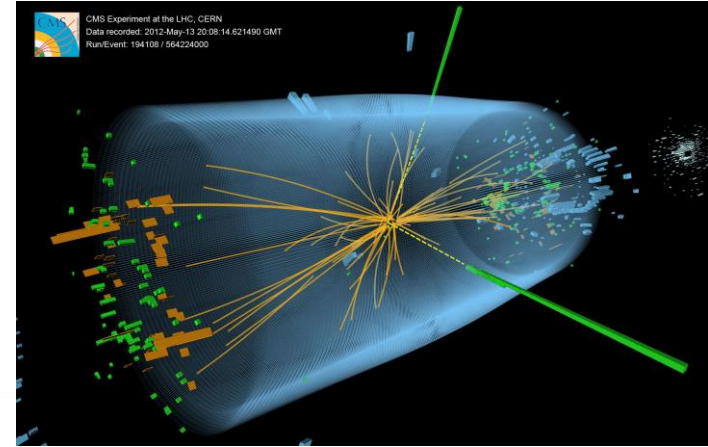
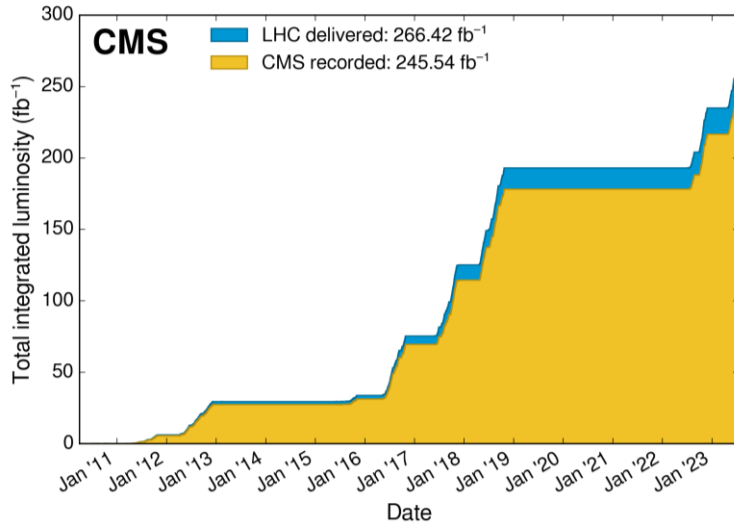
- Active Years: 2011 - 2025
- Maximum beam energy: $\sim 7\text{TeV}/\text{beam}$
- Main collision type: proton - proton
- LHC is a “top quark factory”





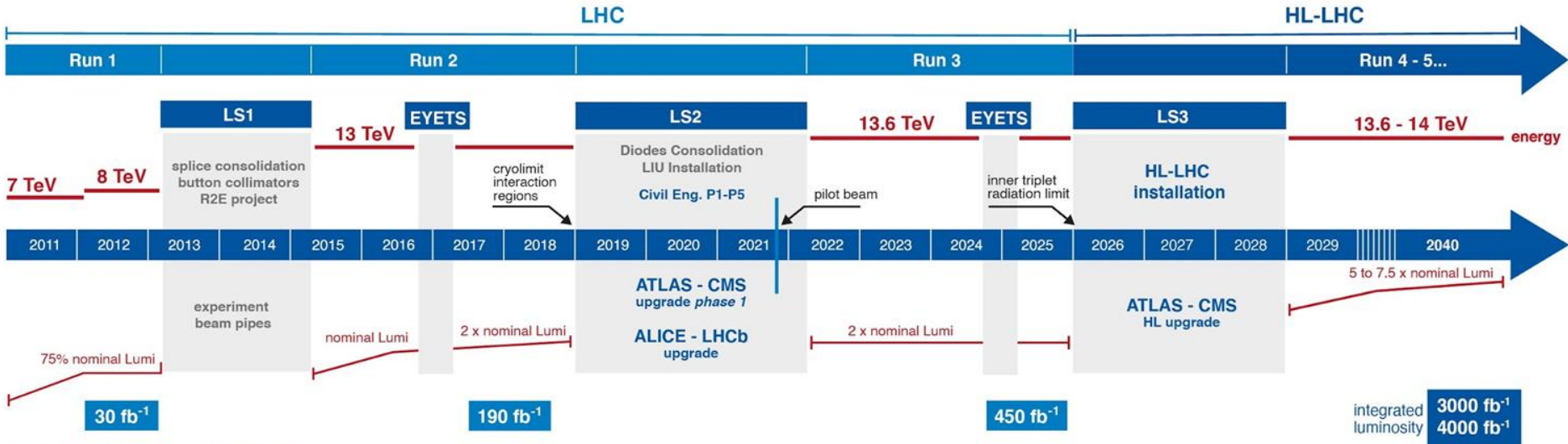
High Luminosity – Large Hadron Collider (HL-LHC)

- Projected Active Years: 2029 - ~2040
- Civil engineering work began
 - June 15, 2018
- Projected center-of-mass energy: ~14 TeV
- Projected integrated luminosity 3000 fb^{-1} – 4000 fb^{-1}





LHC / HL-LHC Plan



HL-LHC TECHNICAL EQUIPMENT:



HL-LHC CIVIL ENGINEERING:



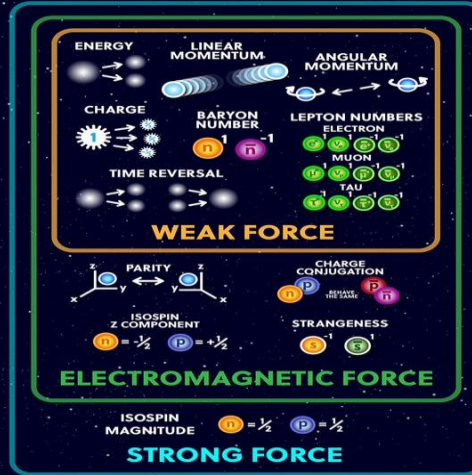
Standard Model Review

THE STANDARD MODEL OF PARTICLE PHYSICS

THE STANDARD MODEL



CONSERVATION LAWS



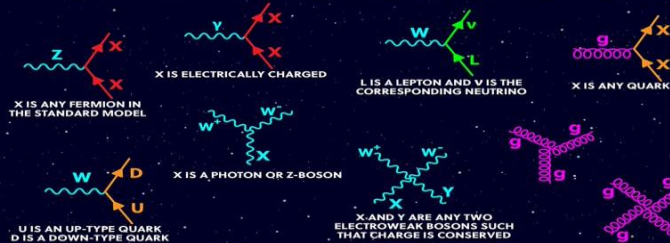
FORCE INTERACTIONS



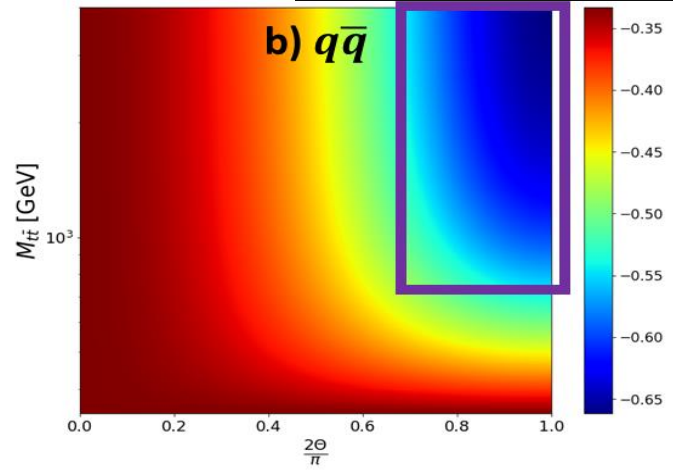
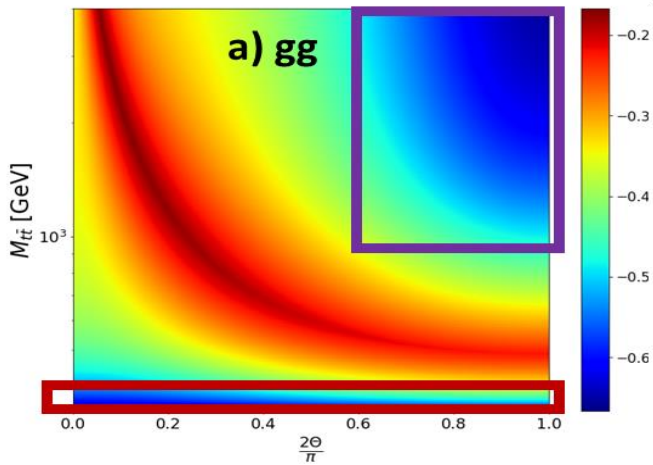
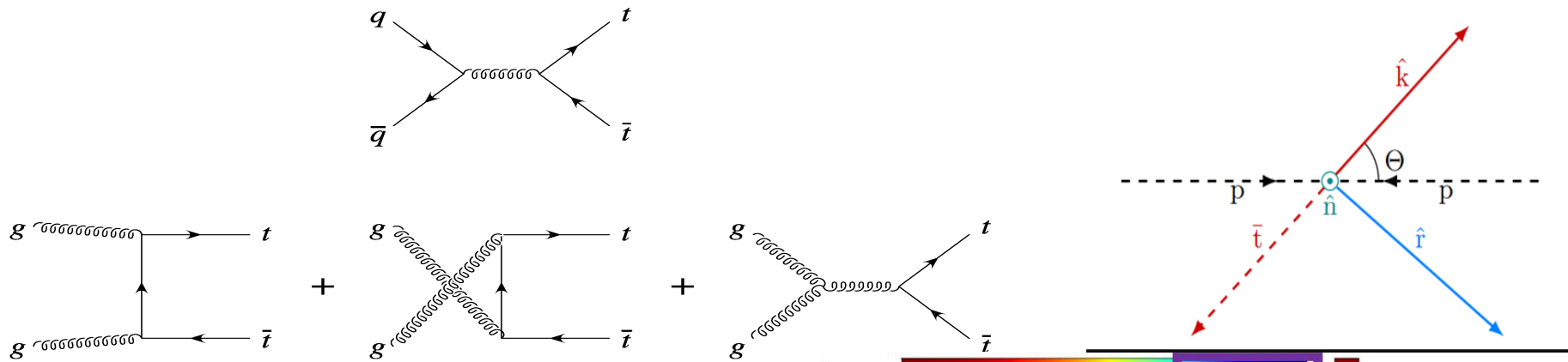
ALL THE FUNDAMENTAL PARTICLES



STANDARD MODEL INTERACTIONS



Top Quark Production Theory

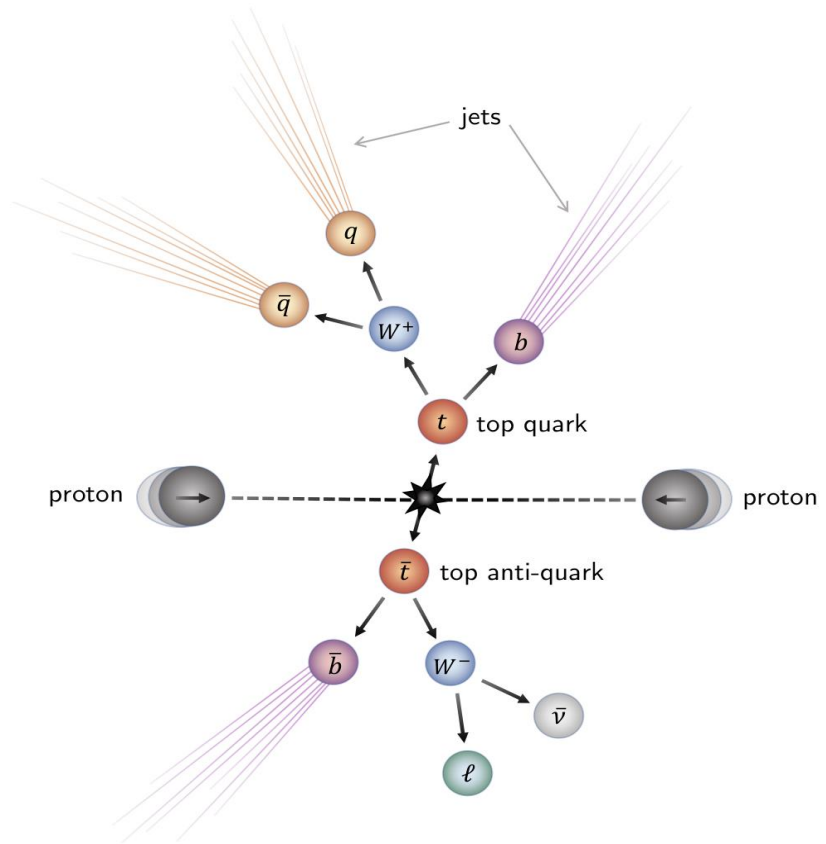
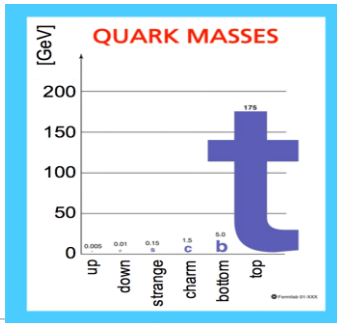




Top Quark Decay Signature

- Because of its mass, it decays quickly
- 2 b-jets and 2 pairs of lepton – neutrinos (90 % of the time)
- Quark – anti quark pairs

$$\underbrace{\frac{1}{m_t}}_{\text{production } 10^{-27} \text{ s}} < \underbrace{\frac{1}{\Gamma_t}}_{\text{lifetime } 10^{-25} \text{ s}} < \underbrace{\frac{1}{\Lambda_{\text{QCD}}}}_{\text{hadronization } 10^{-24} \text{ s}} < \underbrace{\frac{m_t}{\Lambda^2}}_{\text{spin-flip } 10^{-21} \text{ s}}$$

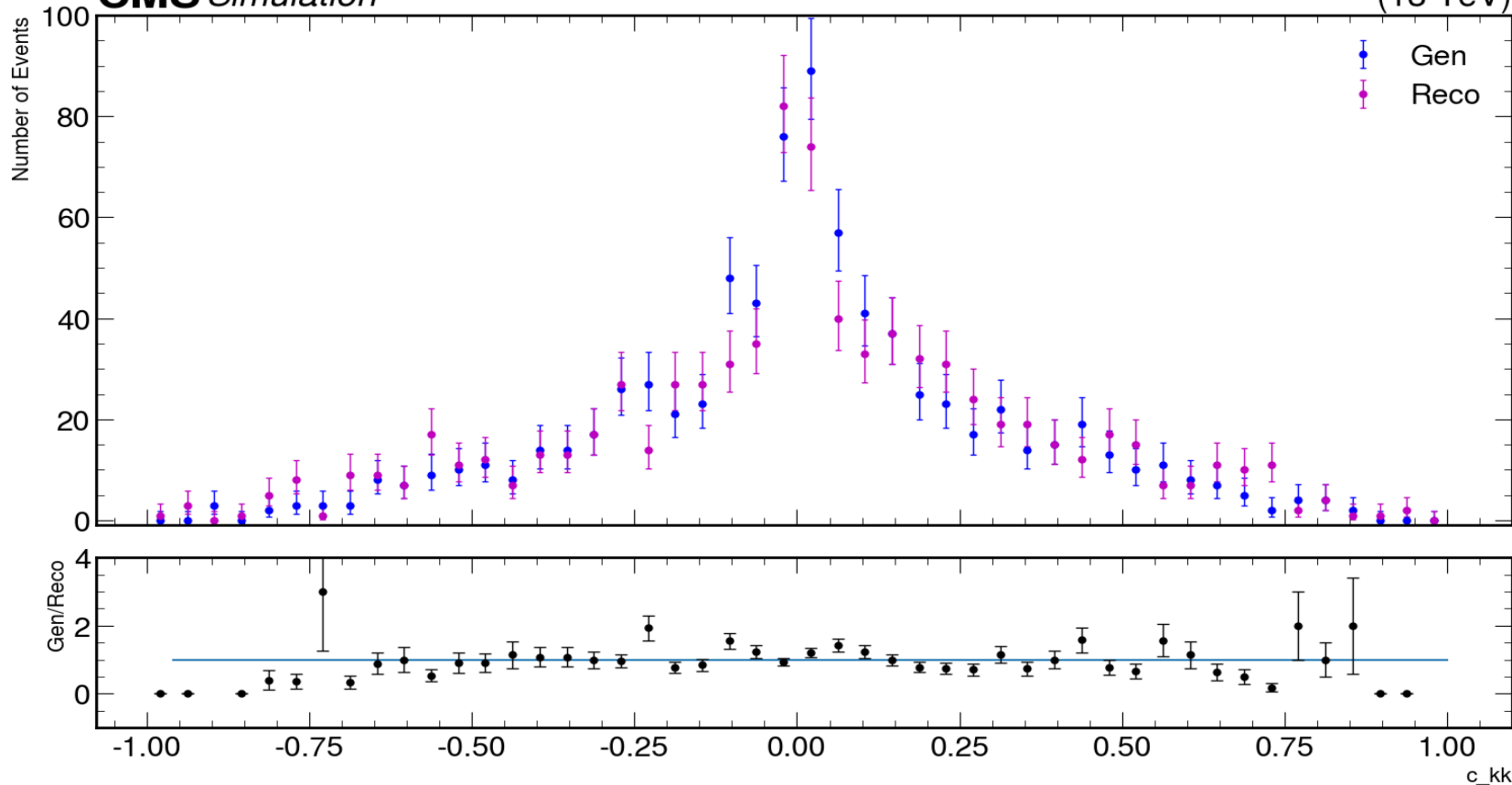




Methods and Analysis

CMS *Simulation*

(13 TeV)





Results

- Measure the spin correlations and polarization of the top quark with HL-LHC Monte Carlo
- For Loop → NumPy: array-based computing to decrease the amount of time it takes to select these events
- Bell Inequality tests to interpret spin correlation
 - <https://arxiv.org/pdf/2102.11883.pdf>
- Measure entanglement in top quark pairs
 - <https://arxiv.org/abs/2003.02280>



Acknowledgments

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 - Grace Bowling
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References

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- [https://cernbox.cern.ch/s/LBfsBkVKOKejYKJSlides:](https://cernbox.cern.ch/s/LBfsBkVKOKejYKJSlides)
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