Top Quark Physics at the Large Hadron Collider

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Outline

- **CERN**
- **The Large Hadron Collider (LHC)**
- **Top Physics – Production and Decay**
- **Top Mass in the Dilepton Channel**

CERN

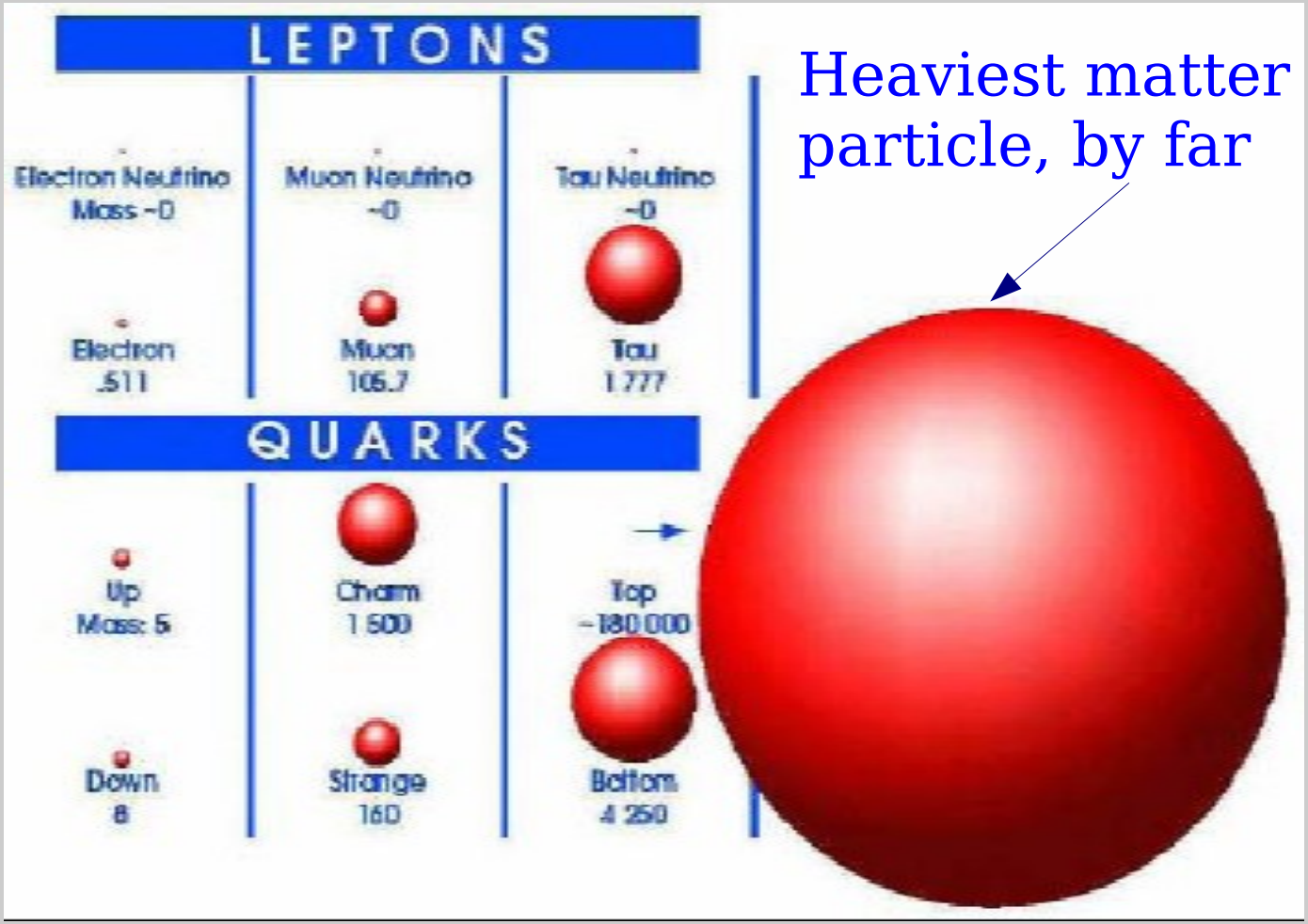
The European Organization for Nuclear Research

- The world's largest particle physics laboratory and research center, located outside Geneva Switzerland on the Swiss-French border
- Founded in 1954 as a multinational collaboration
- Now includes 20 European Member States
  - USA, Russia, EU, UNESCO, Japan, Turkey and Israel have observer status
- Flagship project: the LHC

Large Hadron Collider (LHC)

- 14-TeV proton-proton accelerator
- Currently under construction:
  - First beams, 2007
  - First physics runs 2008
- A hadronic 'discovery' accelerator
  - Will search for Higgs, supersymmetry, quark-gluon plasmas, CP-violation, physics beyond standard model
- Also important for top quark physics
  - A “Top Factory”

Top Quarks

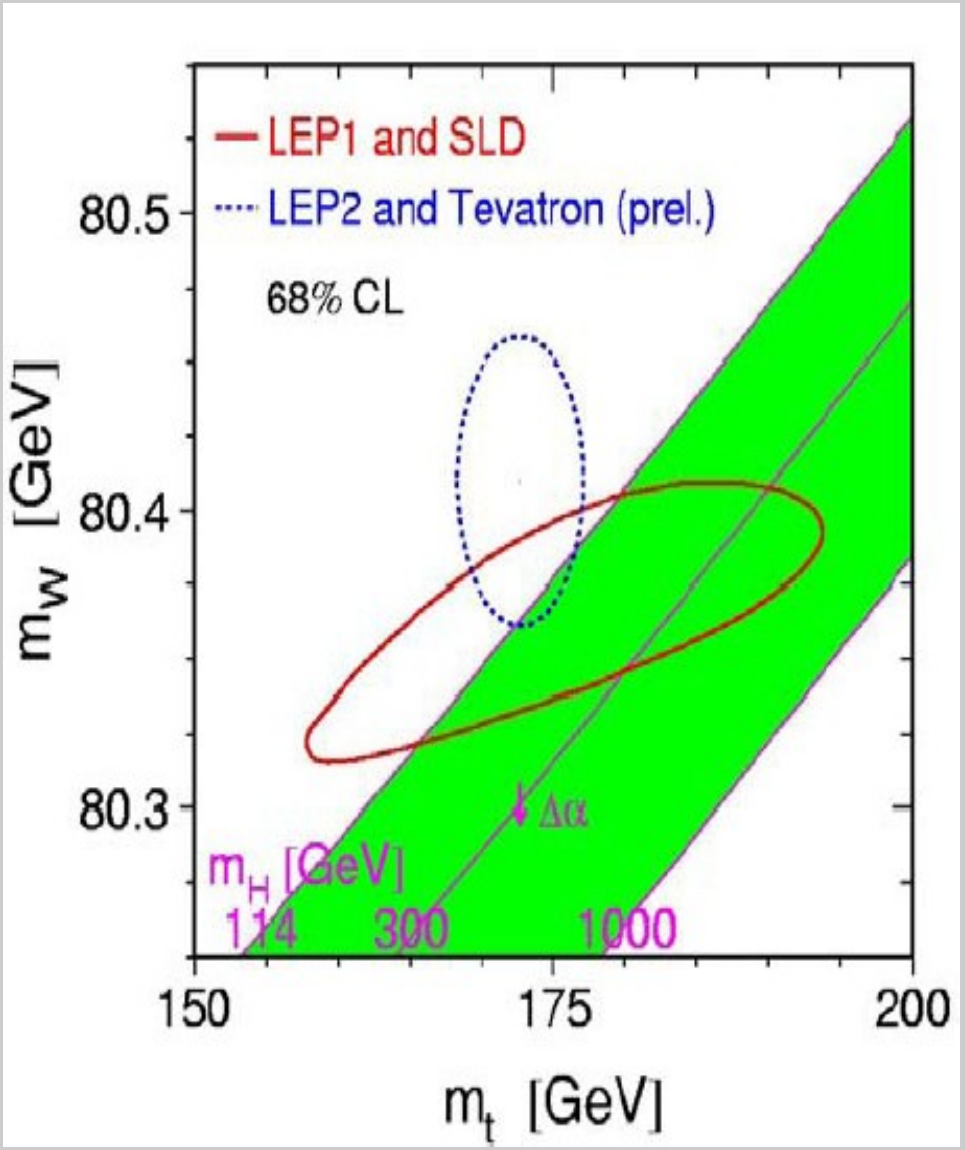


- Detected only ten years ago
- Very heavy – hard to produce
- Much still measured with only little precision
  - Mass
  - Spin
  - Polarization
  - Decays
  - Bare quarks?

Top Quarks Beyond the SM

- Can also be used to probe physics beyond the Standard Model

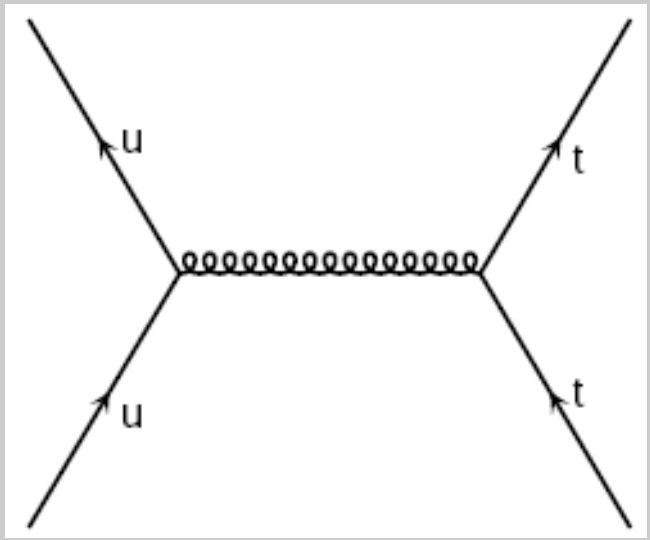
- Top mass constrains Higgs mass (light Higgs favored by top mass data)



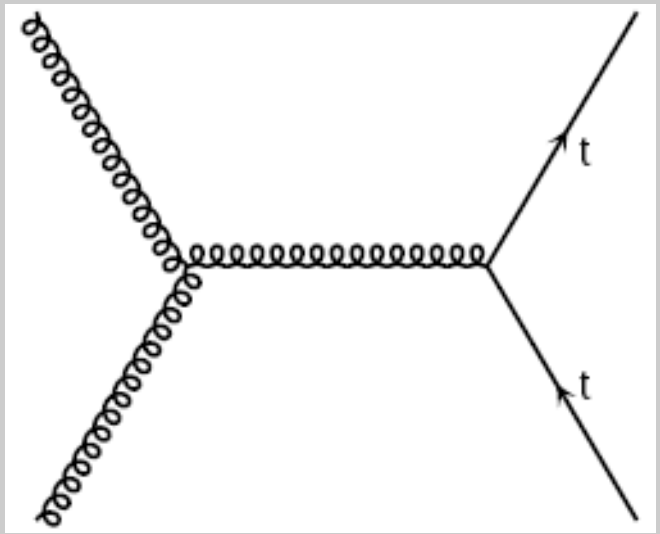
Top Quark Production

Dominant production mechanism is top-antitop pair production through either

Quark-antiquark annihilation



Gluon-gluon fusion



Tevatron:	85%	15%
LHC:	5%	95%

Top Quark Decay and Detection

- Tops decay very quickly into a b quark and W boson. The W can then decay either leptonically or hadronically.
- This gives three channels of top-antitop decay:

  Dilepton channel:

  μ or e only: 5%

  $$t\bar{t} \longrightarrow l^+\nu_l b\ l^-\bar{\nu}_l\bar{b}$$

  Lepton + jets channel:

  μ or e only: 30%

  $$t\bar{t} \longrightarrow bl^+\nu_l\ \bar{b}q\bar{q}$$

  All-jets channel:

  44%, messy

  $$t\bar{t} \longrightarrow b\bar{q}q\ \bar{b}q\bar{q}$$

- Which is best for measurements?

  Leptons easy to measure

  Jets less so

  Neutrinos not at all

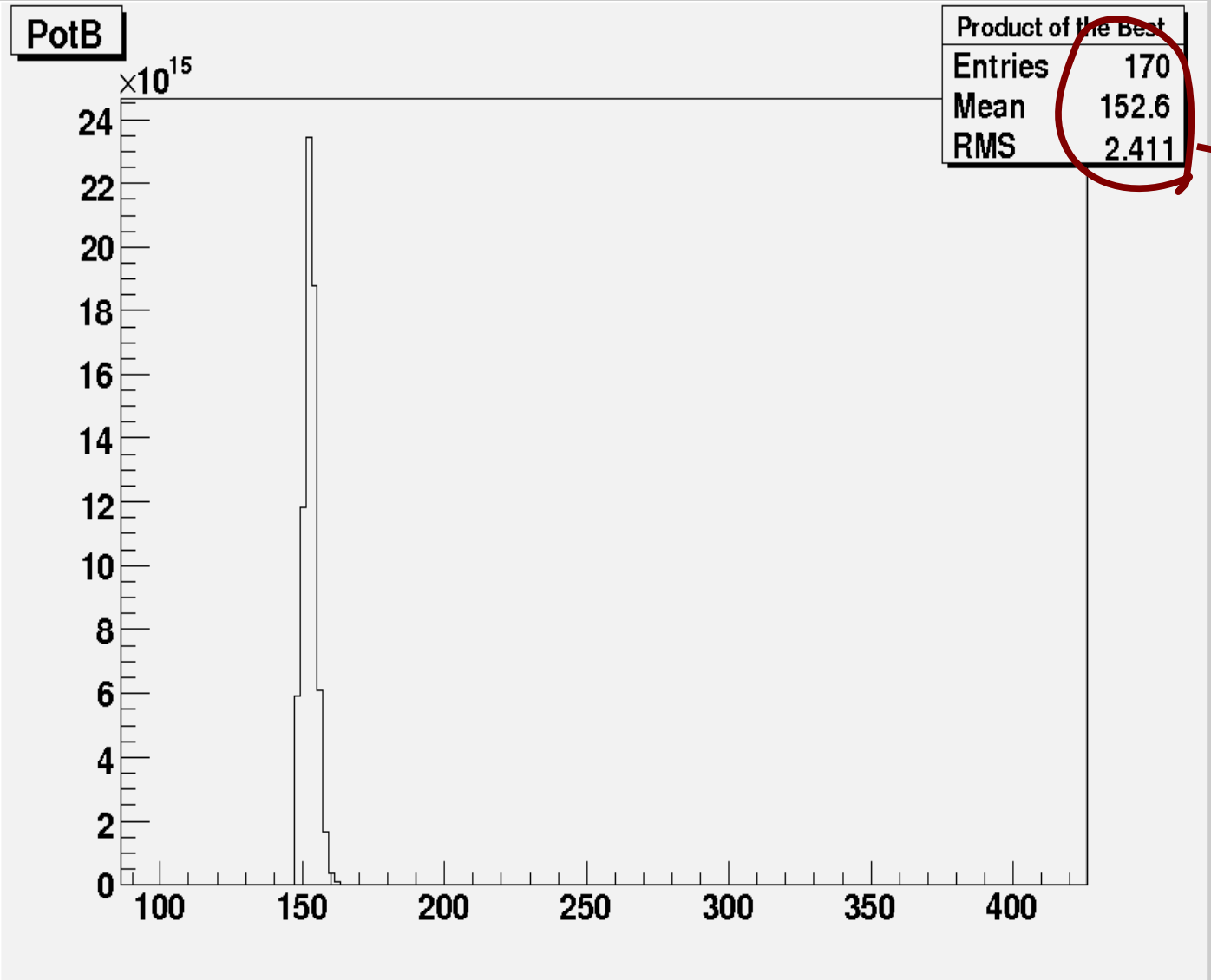
Top Mass in the Dilepton Channel

- Have very accurate lepton measurements, but nothing at all for the neutrinos.
- Task is to determine eight unknowns (four-momentum components of the two neutrinos) from eight kinematical equations.
- Use a geometrical approach for each quark
  - Constant E_t gives a circle in momentum space
  - Varying E_t produces a paraboloid
  - Points of constant M_t lie on a plane section of the paraboloid – i.e., an ellipse
  - Project the ellipse onto the transverse momentum plane
- Ellipses for top and antitop should match!
- See Dalitz, R.H.& Goldstein, G.R. 1992 *Phys. Rev.* **D45**, 1531-1543

The Project

- My project was to take code from the CDF experiment at Fermilab that measures the mass of the top quark using the dilepton channel approach just described and adapt it to the ATLAS experiment.
- Then I would test the code with samples of increasingly complex and realistic data, in preparation for real data from ATLAS.
- The work is still in progress after many complications, most rather technical and uninteresting.

An Interesting Complication



Top mass:
152 GeV
(± ~10 GeV)

Code gives very low results for real Fermilab data (through 2004)

'Official' mass:
174±3.4 GeV

Acknowledgments

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