Tevatron / LHC Interplay

Chris Quigg

Fermilab

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arXiv:0908.3660 lutece.fnal.gov/PartonLum

Ellis, Stirling, Webber, QCD & Collider Physics
MRSW08NLO examples + RKE Lecture 3, SUSSP 2009
LHC physics run begins soon . . .

The Large Hadron Collider will run in 2010–2011 at 3.5 TeV per beam, to accumulate $\sim 1 \text{ fb}^{-1}$.

- At what point will the LHC begin to explore virgin territory and surpass the discovery reach of the Tevatron experiments CDF and D0?
- How is the physics potential compromised by running below 14 TeV?
Parton Luminosities + Prior Knowledge = Answers

Taking into account \( 1/\hat{s} \) behavior of hard scattering,

\[
\frac{\tau \, d\mathcal{L}}{\hat{s} \, d\tau} \equiv \frac{\tau/\hat{s}}{1 + \delta_{ij}} \int_{\tau}^{1} \frac{d\tau}{x} \left[ f_i^{(a)}(x)f_j^{(b)}(\tau/x) + f_j^{(a)}(x)f_i^{(b)}(\tau/x) \right]
\]

is a convenient measure of parton \( ij \) luminosity.

\( f_i^{(a)}(x) \): pdf; \( \tau = \hat{s}/s \)

\[
\sigma(s) = \sum_{\{ij\}} \int_{\tau_0}^{1} \frac{d\tau}{\tau} \cdot \frac{\tau \, d\mathcal{L}_{ij}}{\hat{s} \, d\tau} \cdot [\hat{s}\hat{\sigma}_{ij}(\hat{s})]
\]

EHLQ §2; QCD & Collider Physics, §7.3
Parton Luminosity

CTEQ6L1: gg

\begin{align*}
\sqrt{s} & \quad [\text{TeV}] \\
0.9 & \\
2 & \\
4 & \\
6 & \\
7 & \\
10 & \\
14 & \\
\end{align*}
Parton Luminosity

CTEQ6L1: $u\bar{d}$

Parton Luminosity [nb]

$\sqrt{s}$ [TeV]
Parton Luminosity (light quarks)

CTEQ6L1: $qq$

Parton Luminosity [nb]

$\sqrt{s}$ [TeV]

0.9 TeV

2 TeV

4 TeV

6 TeV

7 TeV

10 TeV

14 TeV

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Luminosity Ratios

CTEQ6L1: gg

\( gg \rightarrow t\bar{t} \times 150 \)

\[ \sqrt{s} \text{ [TeV]} \]

\[ \text{Ratio to Tevatron} \]

- R.9
- R4
- R6
- R7
- R10
- R14

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Luminosity Ratios

CTEQ6L1: ud

$q\bar{q} \rightarrow t\bar{t}$

$\times 6.7$

Ratio to Tevatron

R0.9
R2
R4
R6
R7
R10
R14

$\sqrt{s} [\text{TeV}]$

$10^3$
$10^2$
$10^1$
$10^0$
$10^{-1}$
$10^{-2}$
$10^{-3}$
$2 \times 10^{-2}$
$2 \times 10^{-1}$
$10^{-1}$
Luminosity Ratios

CTEQ6L1: $gg$

$gg \to H$

$\times (20, 38, 70) @ \sqrt{s} = 7, 10, 14$ TeV

$\approx$ Tevatron at $(500, 260, 140) \text{ pb}^{-1}$
Luminosity Ratios

CTEQ6L1: $gg \rightarrow H$

$\times (30, 65, 100) \at \sqrt{s} = 7, 10, 14$ TeV

$\approx$ Tevatron at $(330, 150, 100)$ pb$^{-1}$

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Luminosity Ratios

CTEQ6L1: $u\bar{d}$

$q\bar{q} \rightarrow VV$

$x(4.8, 7.3, 10.7) @ \sqrt{s} = 7, 10, 14 \text{ TeV}$
Luminosity Ratios

CTEQ6L1: \[ u\bar{d} \]

\[ x(34, 70, 120) \text{ at } \sqrt{s} = 7, 10, 14 \text{ TeV} \]
\[ \approx \text{Tevatron at } (300, 140, 83) \text{ pb}^{-1} \]
Luminosity Ratios

CTEQ6L1: qq

\[ qq \rightarrow \text{jets} \]

\[ \times (135, 220, 340) \quad @ \quad \sqrt{s} = 7, 10, 14 \text{ TeV} \]

\[ \approx \text{Tevatron at } (75, 45, 30) \text{ pb}^{-1} \]
Some Absolute Rates

Cross section [fb]

R. K. Ellis, MCFM

7 TeV 2 TeV
Leading-Order Analysis

At a few hundred pb$^{-1}$, the 7-TeV LHC enters terrain inaccessible to the Tevatron at 10 fb$^{-1}$

*Useful starting point; but leaves out many detailed studies & precision measurements in progress at the Tevatron.*

Should know in 6 months how gracefully LHC starts up
Deconstruct the Slogans

- Run the Tevatron until LHC has found or excluded the light Higgs boson (and established $H \rightarrow b\bar{b}$).
- If a discovery were in reach, we should have hints now.
- Tevatron is a quark collider, LHC is a gluon collider.
- It will take years for LHC experiments to publish meaningful physics papers.
- The Tevatron will become irrelevant overnight.
- The Tevatron is old; it will collapse.
- The LHC is new; it will take years to work.
Deconstruct the Slogans

Run the Tevatron until LHC has found or excluded the light Higgs boson (and established $H \rightarrow b\bar{b}$).

- What could Tevatron contribute?
  - On current path, Tevatron cannot discover SM Higgs exclusion / evidence / “early” $b\bar{b}$ in $HV$
  - How seriously would you take exclusion?

- What would be required?
  - 20 fb$^{-1}$? / raised $\langle L \rangle$? / New Si? / Shutdown?

- Cost and opportunity cost
  - Are the people there to execute the program?
Planning, American Style
Opportunities Not (Yet) Taken at the Tevatron

- **CDF & D0:**
  - Study of minimum-bias events / particle production
  - Charm physics (in light of $D^0\bar{D}^0$ mixing)

- **Tevatron Collider Program:**
  - $\sigma_{\text{tot}}, \rho \equiv \text{Re/Im of forward elastic amplitude}$
  - (BTeV)

- **21st-Century Fixed-Target Experiments**
  - Charm physics (in light of $D^0\bar{D}^0$ mixing)
  - $\nu_e$ scattering
  - $\nu_\tau$ experiments (LAr-based)
  - Exotic (decaying?) neutrinos
  - See arXiv:0905.3004