LHC Physics Potential *vs.* Energy

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Fermilab · TUM · LMU

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arXiv:0908.3660 lutece.fnal.gov/PartonLum

EHLQ, *Rev. Mod. Phys.* **56**, 579–707 (1984)
Ellis, Stirling, Webber, *QCD & Collider Physics*
MRSW08NLO examples + RKE Lecture 3, SUSSP 2009

LHC experiments begin soon . . .

The Large Hadron Collider will run for the first part of the 2009-2010 run at 3.5 TeV per beam, with the energy rising later in the run.

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

Parton Luminosities + Prior Knowledge = Answers

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

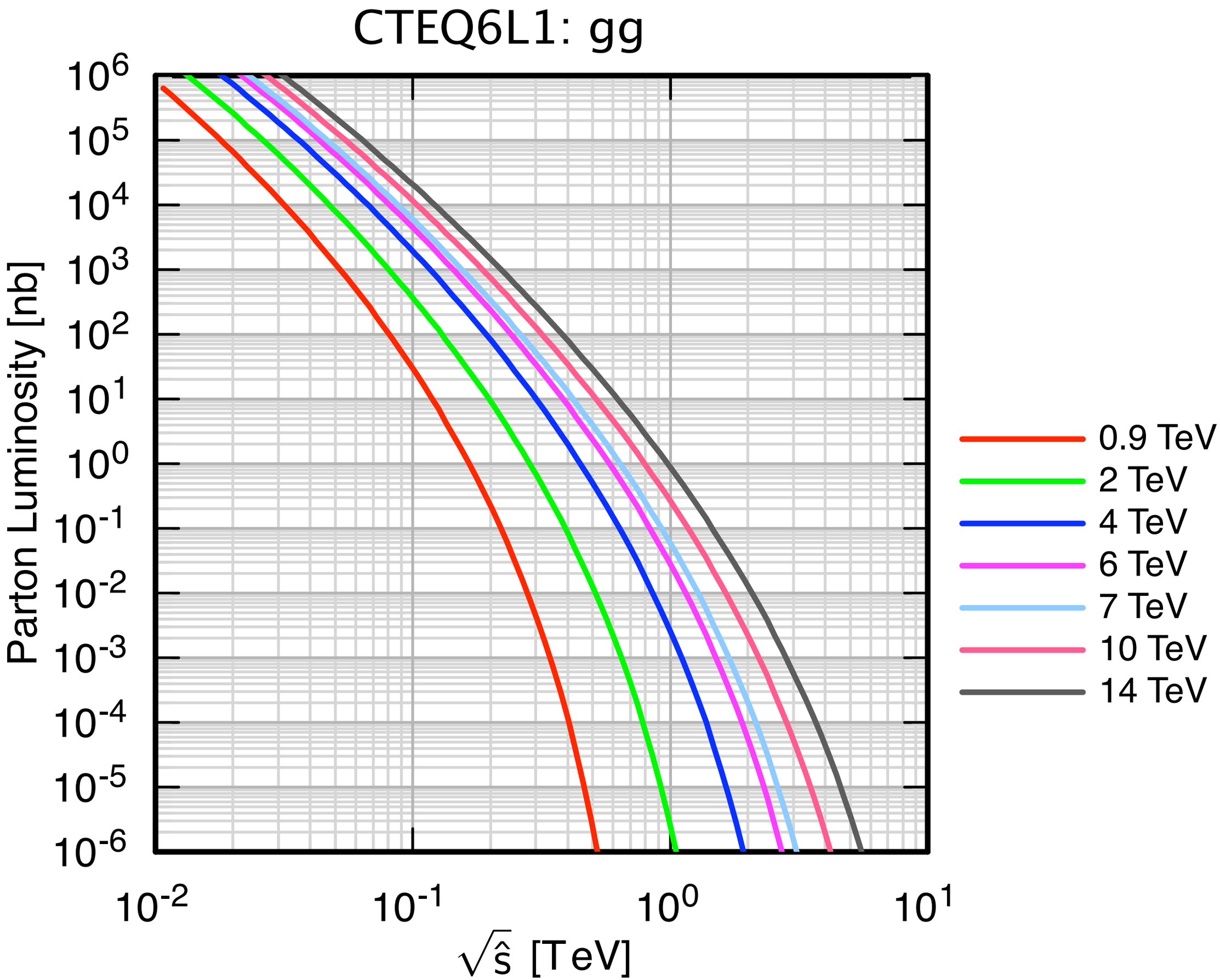
$$\frac{\tau}{\hat{s}}\frac{d\mathcal{L}}{d\tau} \equiv \frac{\tau/\hat{s}}{1+\delta_{ij}}\int_\tau^1 \frac{dx}{x}[f_i^{(a)}(x)f_j^{(b)}(\tau/x) + f_j^{(a)}(x)f_i^{(b)}(\tau/x)]$$

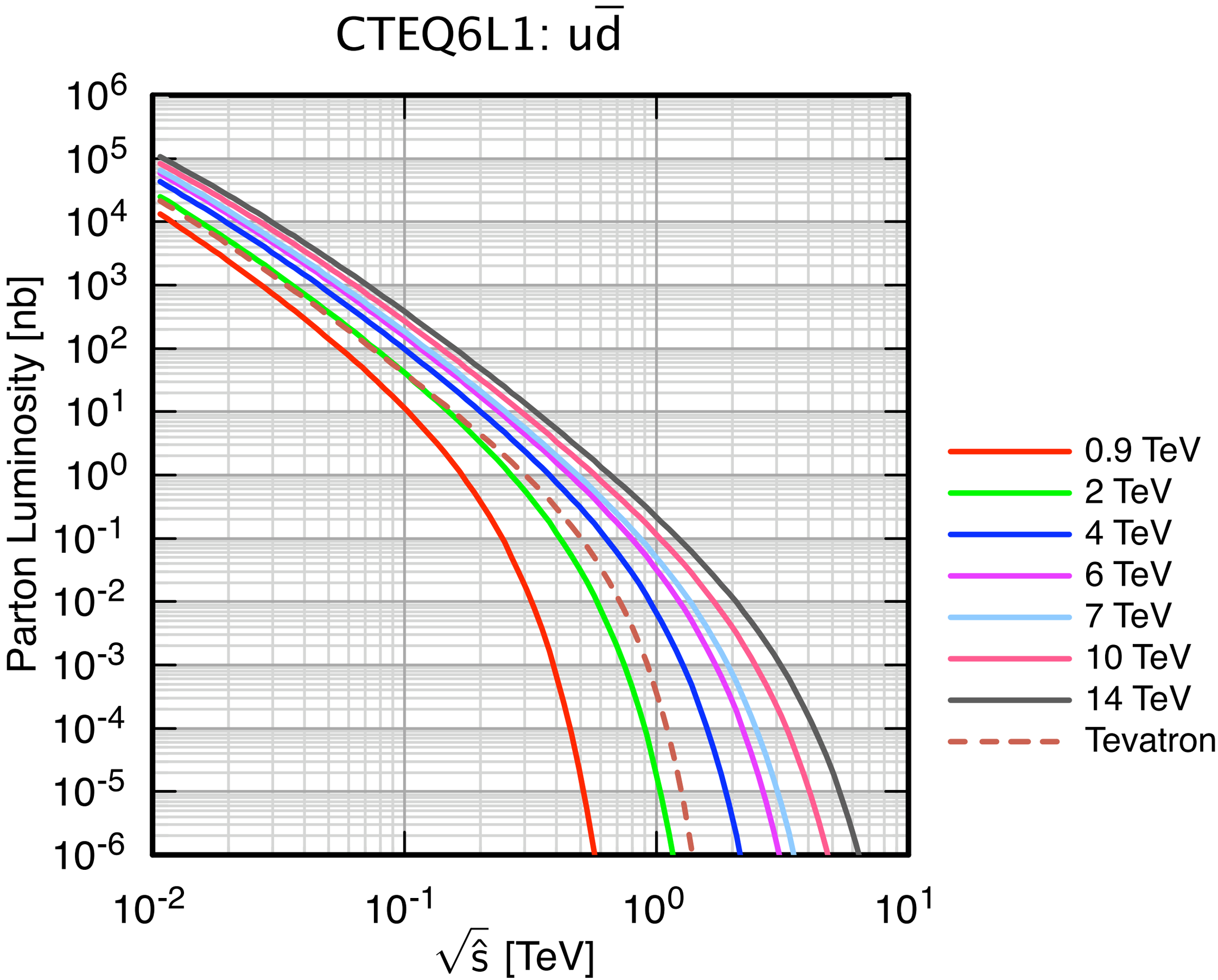
is a convenient measure of parton *ij* luminosity.

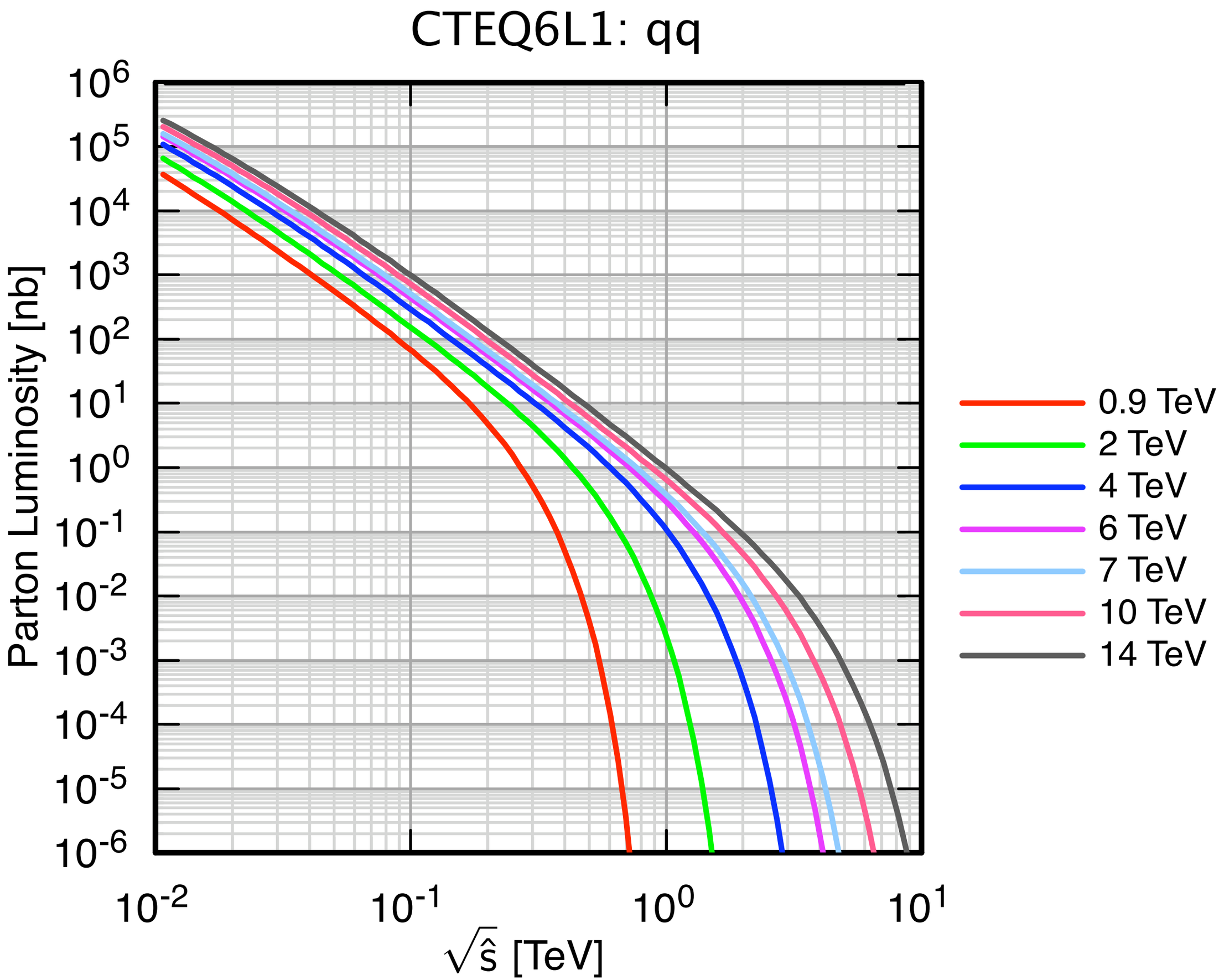
$$f_i^{(a)}(x)\text{: pdf;} \quad \tau = \hat{s}/s$$

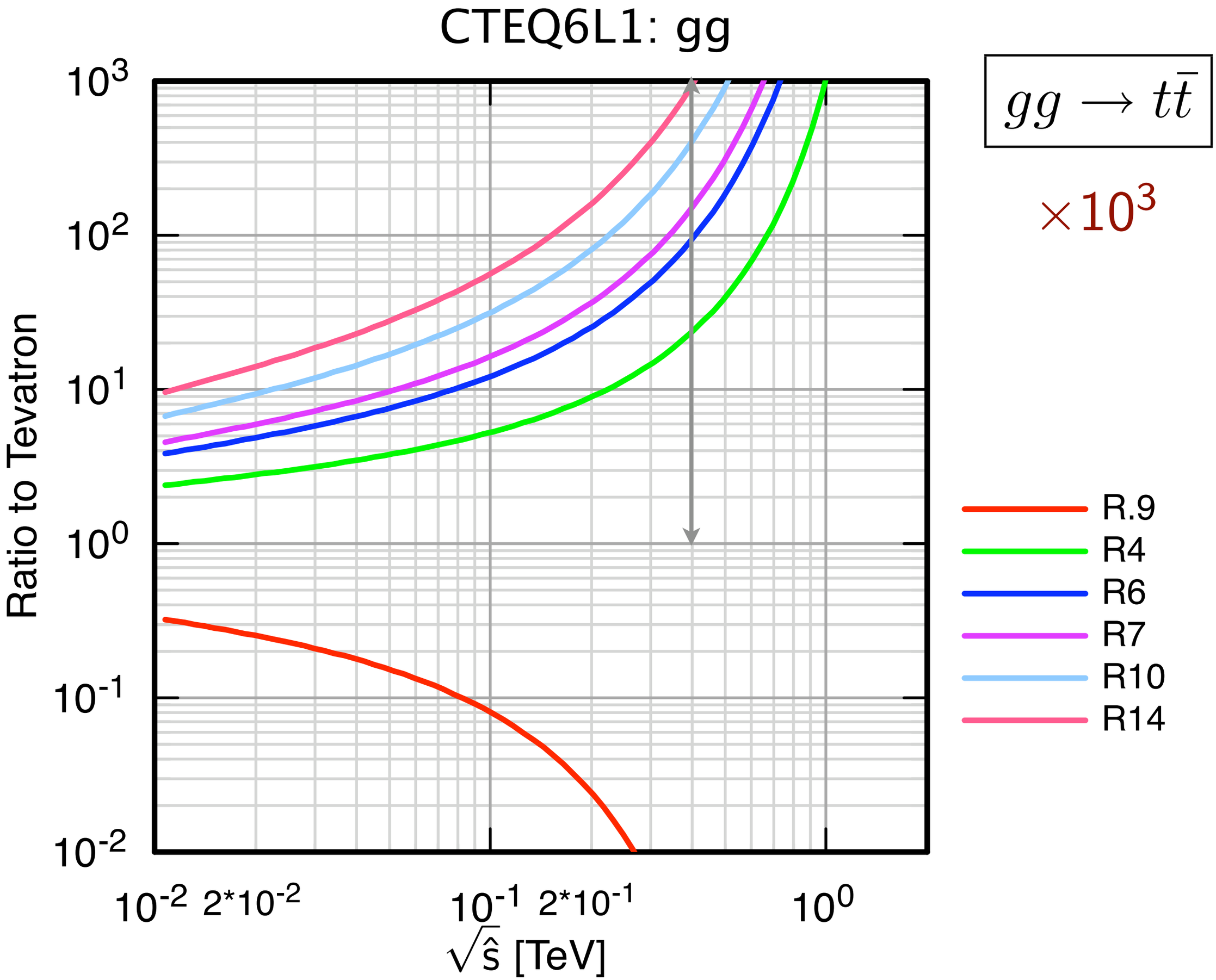
$$\sigma(s) = \sum_{\{ij\}}\int_{\tau_0}^1 \frac{d\tau}{\tau}\cdot\frac{\tau}{\hat{s}}\frac{d\mathcal{L}_{ij}}{d\tau}\cdot[\hat{s}\hat{\sigma}_{ij}(\hat{s})]$$

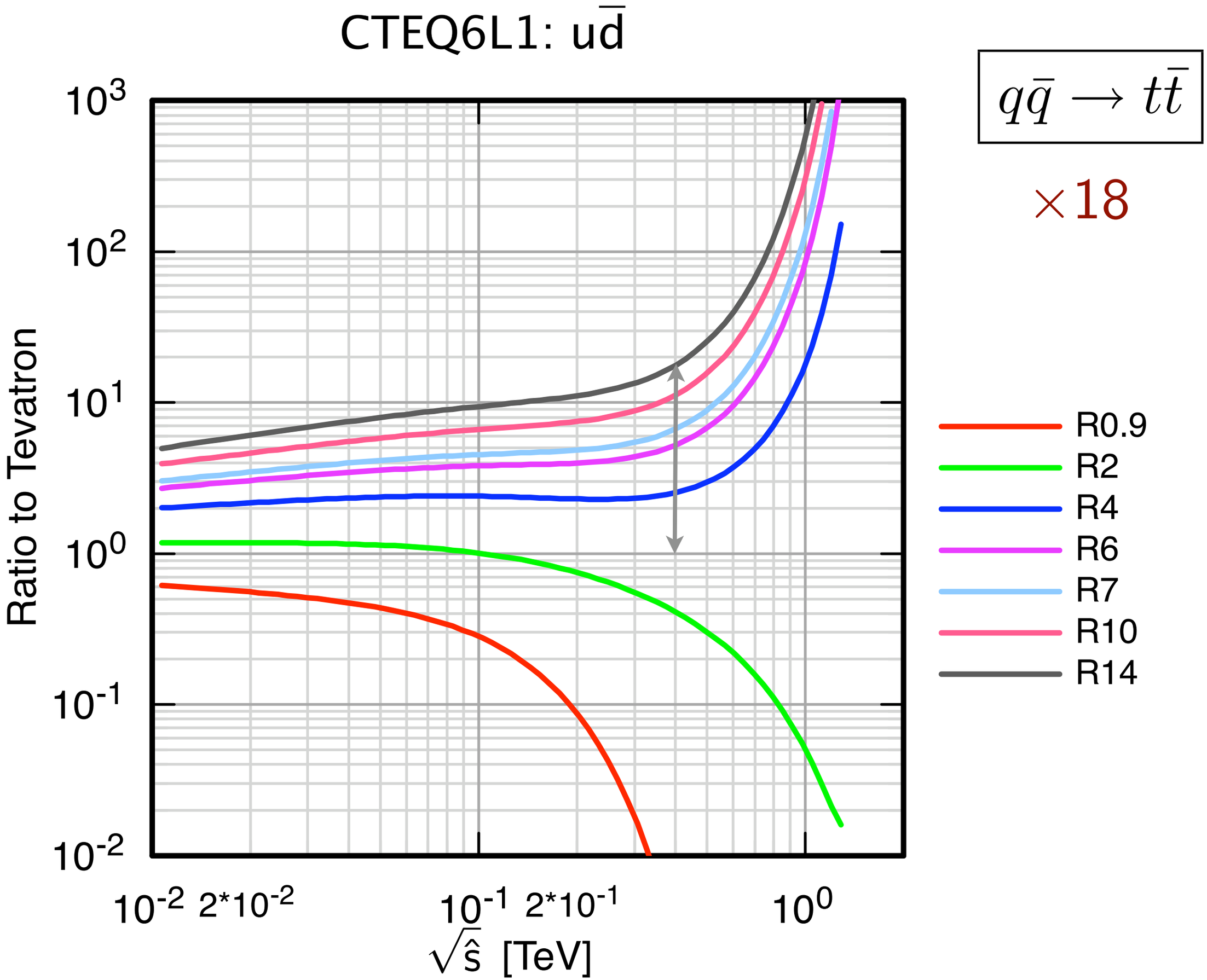
EHLQ §2; *QCD & Collider Physics*, §7.3

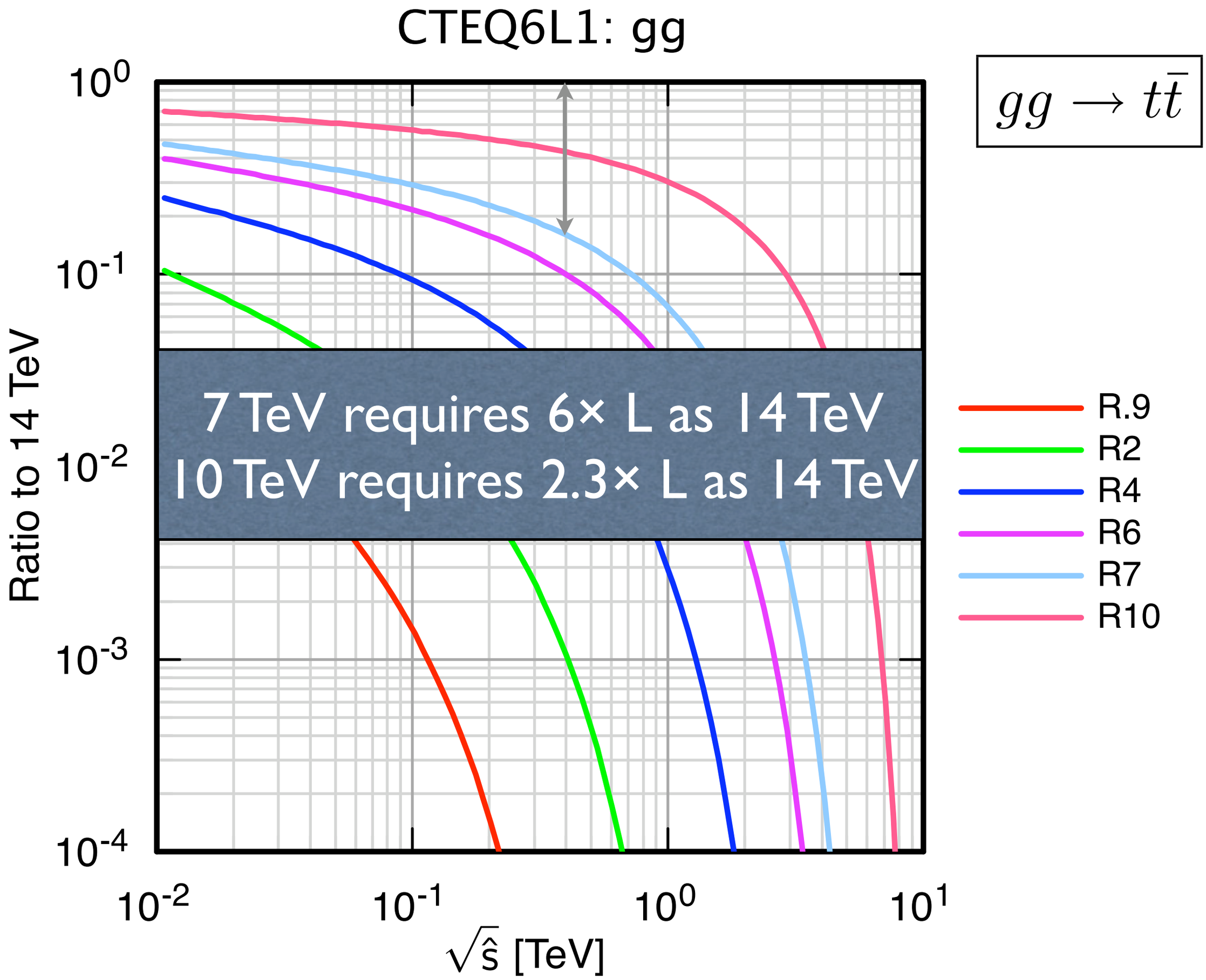

CTEQ6L1: gg
Parton Luminosity [nb]
10^{6}
10^{5}
10^{4}
10^{3}
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-2}
10^{-1}
10^{0}
10^{1}
$\sqrt{\hat{s}}$ [TeV]
0.9 TeV
2 TeV
4 TeV
6 TeV
7 TeV
10 TeV
14 TeV

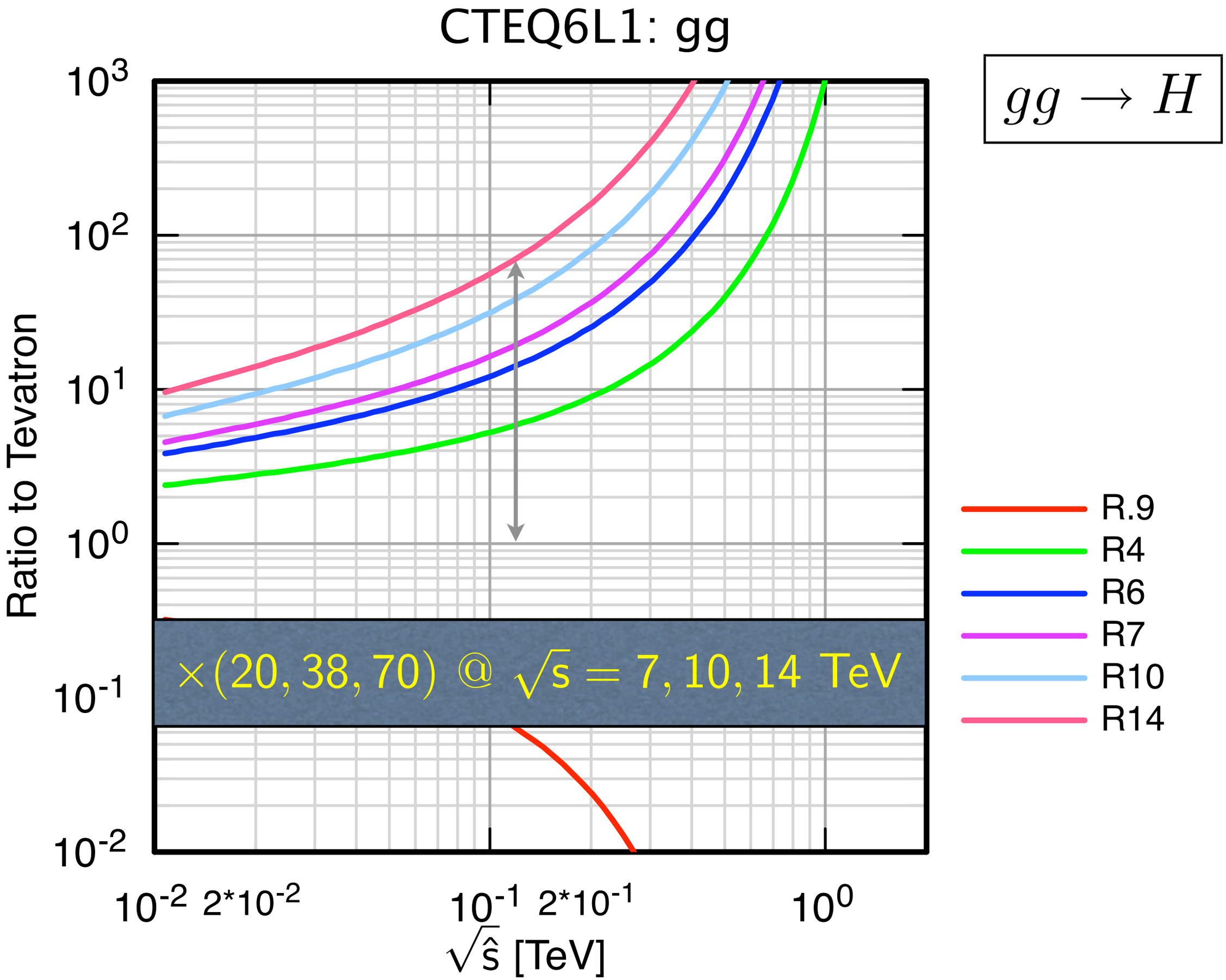

CTEQ6L1: $u\bar{d}$
Parton Luminosity [nb]
10^{6}
10^{5}
10^{4}
10^{3}
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-2}
10^{-1}
10^{0}
10^{1}
$\sqrt{\hat{s}}$ [TeV]
0.9 TeV
2 TeV
4 TeV
6 TeV
7 TeV
10 TeV
14 TeV
Tevatron

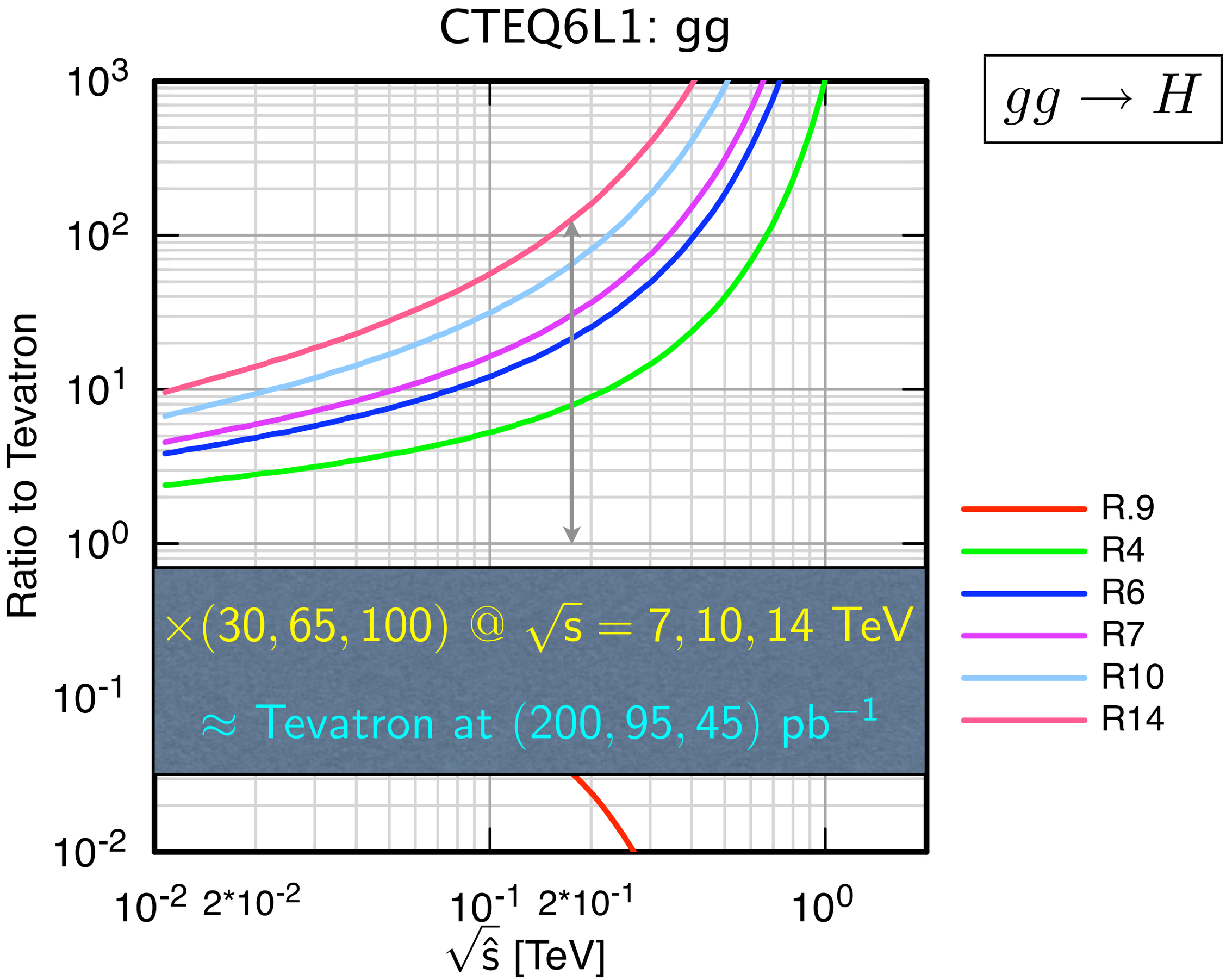

CTEQ6L1: qq
Parton Luminosity [nb]
10^{6}
10^{5}
10^{4}
10^{3}
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-2}
10^{-1}
10^{0}
10^{1}
$\sqrt{\hat{s}}$ [TeV]
0.9 TeV
2 TeV
4 TeV
6 TeV
7 TeV
10 TeV
14 TeV

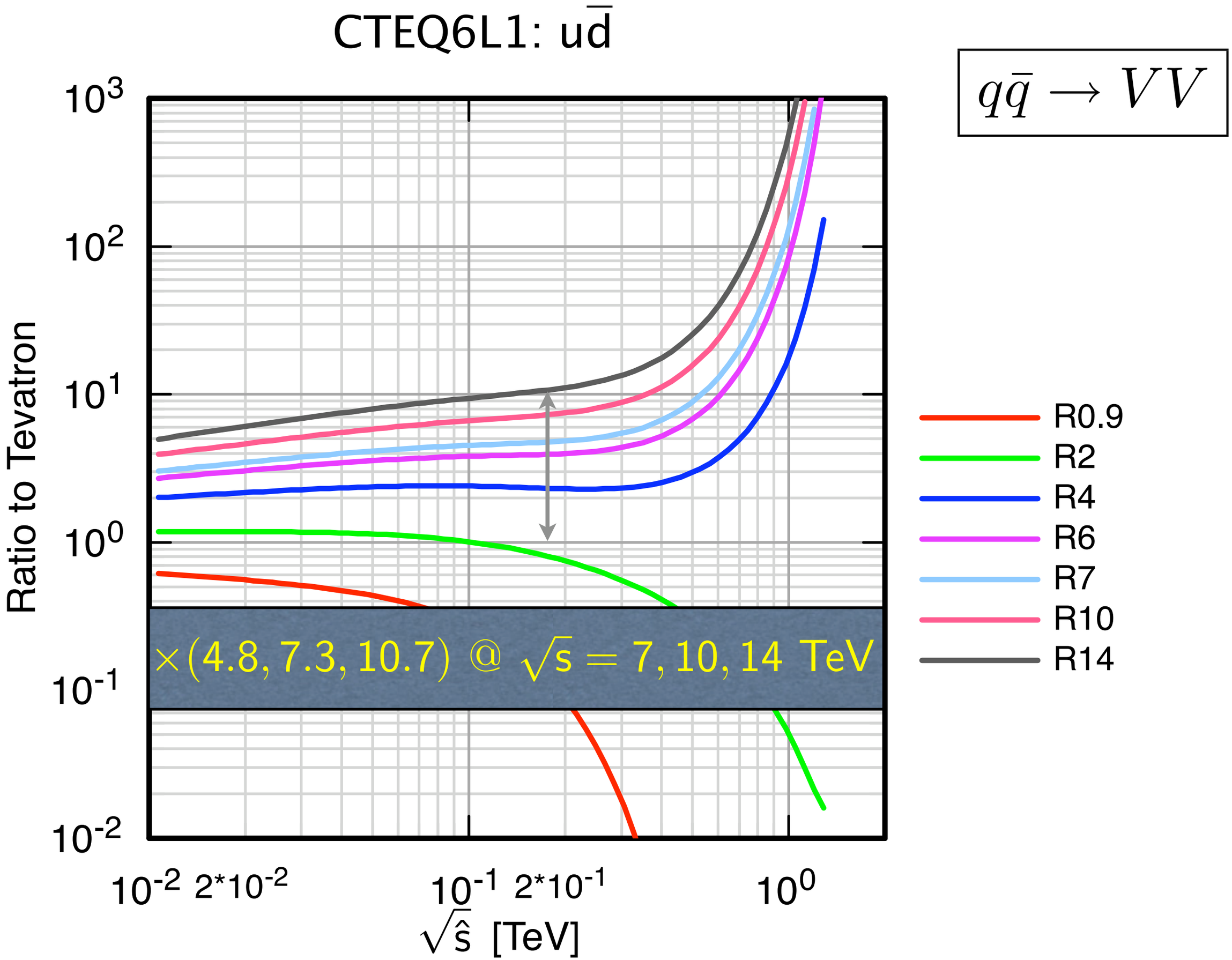

CTEQ6L1: gg
$gg \to t\bar{t}$
$\times 10^3$
Ratio to Tevatron
10^3
10^2
10^1
10^0
10^{-1}
10^{-2}
10^{-2} $2*10^{-2}$
10^{-1} $2*10^{-1}$
10^0
$\sqrt{\hat{s}}$ [TeV]
R.9
R4
R6
R7
R10
R14

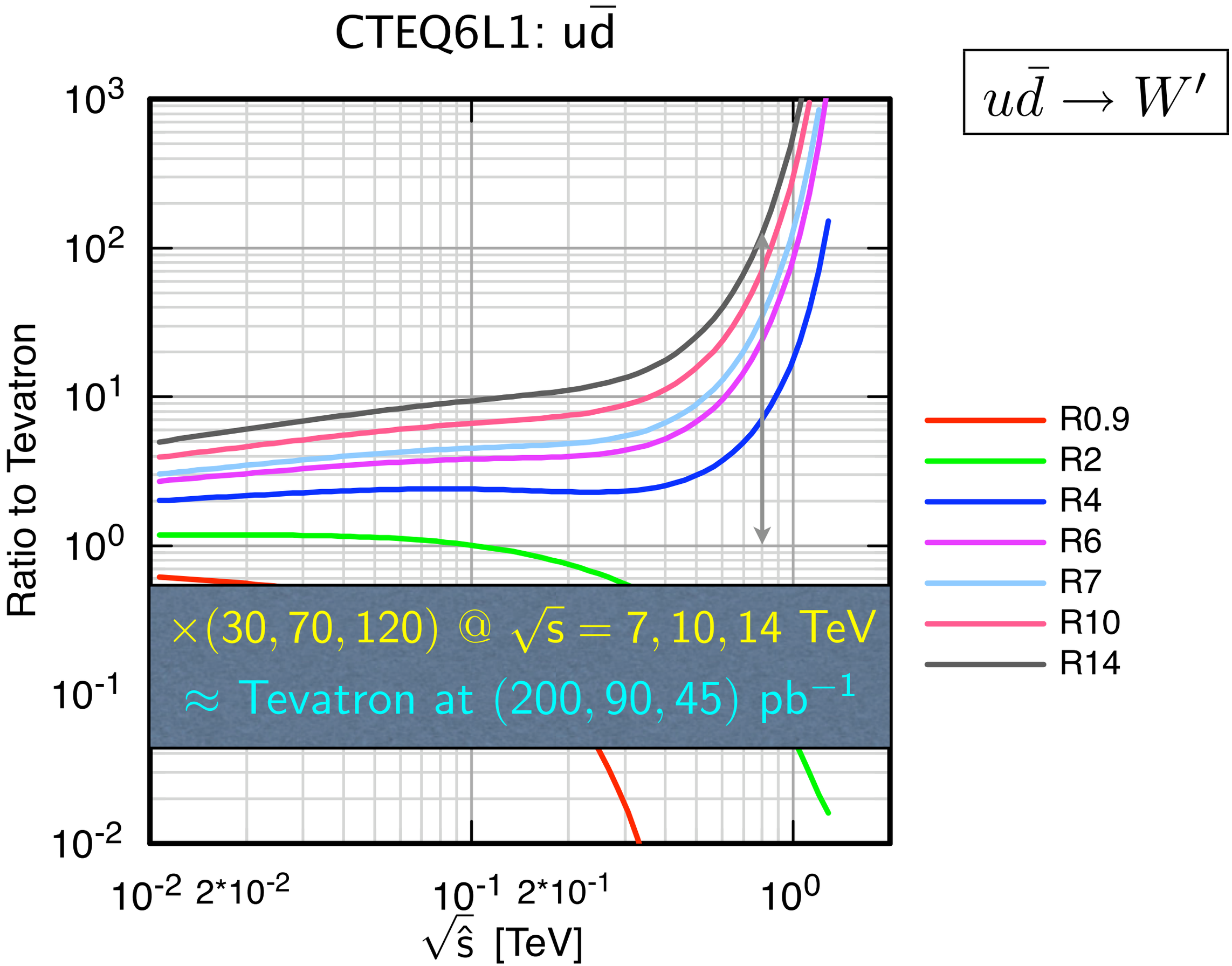

CTEQ6L1: $u\bar{d}$
$q\bar{q} \to t\bar{t}$
$\times 18$
Ratio to Tevatron
10^3
10^2
10^1
10^0
10^{-1}
10^{-2}
10^{-2} $2*10^{-2}$
10^{-1} $2*10^{-1}$
10^0
$\sqrt{\hat{s}}$ [TeV]
R0.9
R2
R4
R6
R7
R10
R14

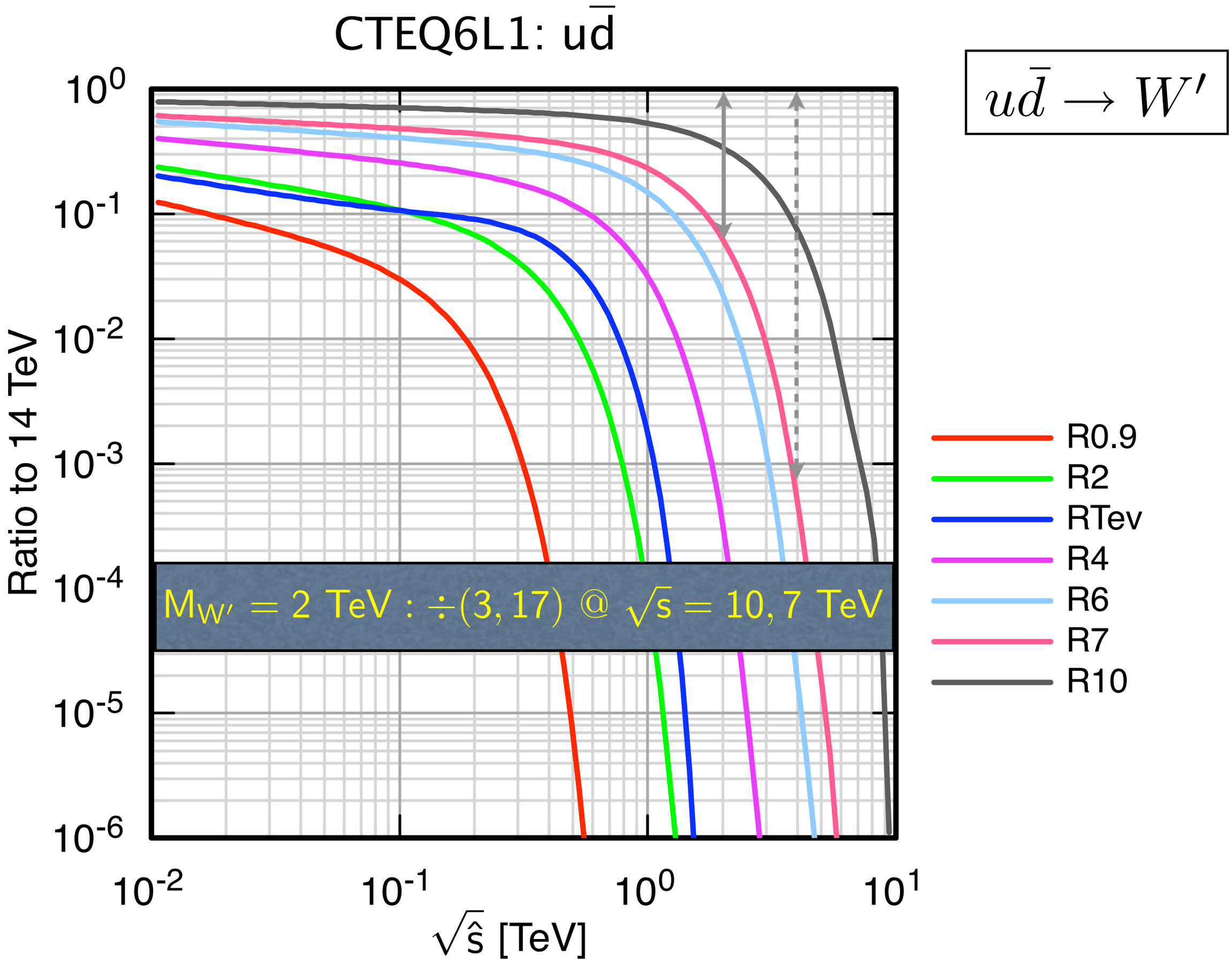

CTEQ6L1: gg
$gg \to t\bar{t}$
7 TeV requires 6× L as 14 TeV
10 TeV requires 2.3× L as 14 TeV
Ratio to 14 TeV
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-2}
10^{-1}
10^0
10^1
$\sqrt{\hat{s}}$ [TeV]
R.9
R2
R4
R6
R7
R10

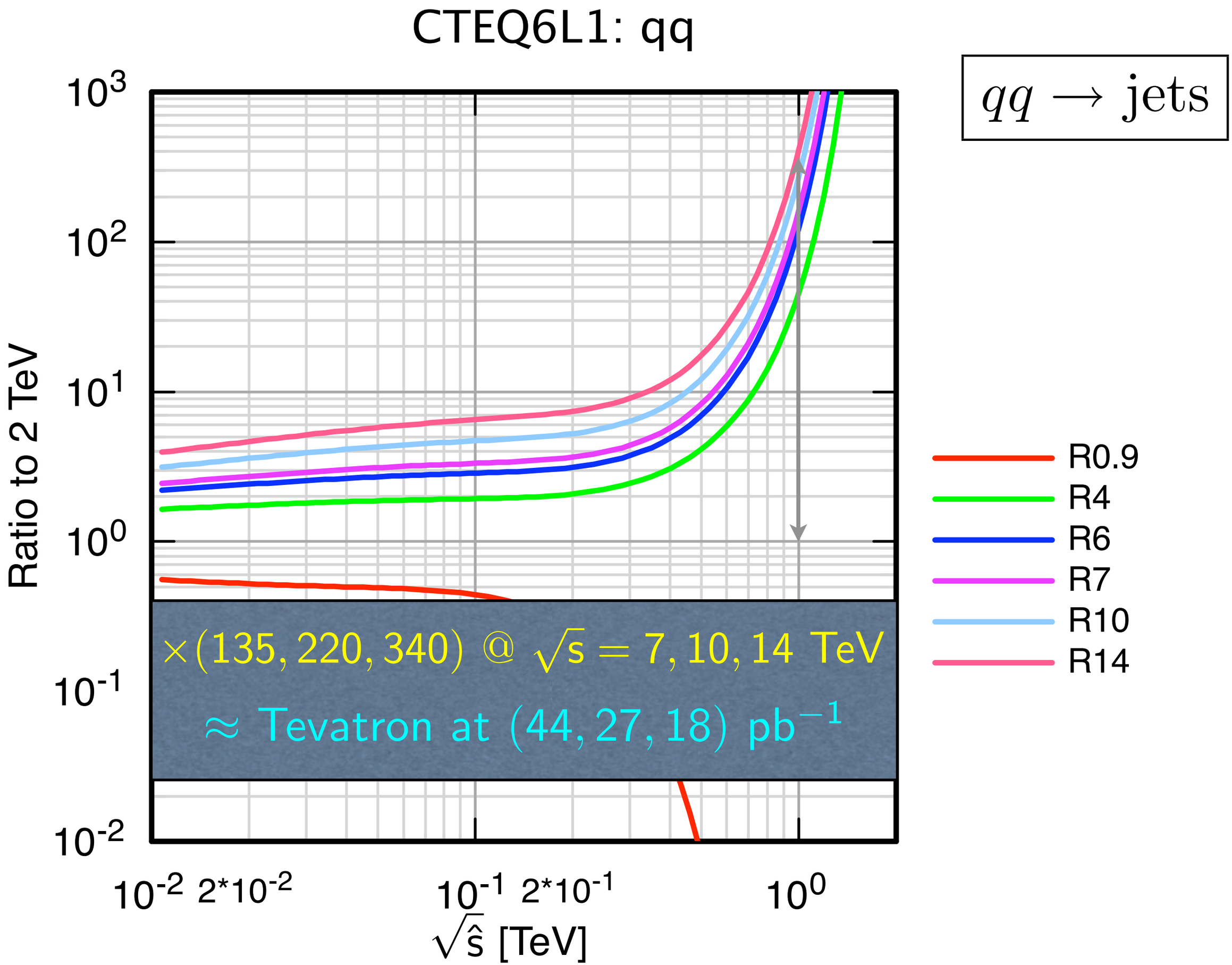

CTEQ6L1: gg
$gg \to H$
Ratio to Tevatron
10^3
10^2
10^1
10^0
10^{-1}
10^{-2}
$\times(20, 38, 70)$ @ $\sqrt{s} = 7, 10, 14$ TeV
10^{-2} $2*10^{-2}$
10^{-1} $2*10^{-1}$
10^0
$\sqrt{\hat{s}}$ [TeV]
R.9
R4
R6
R7
R10
R14

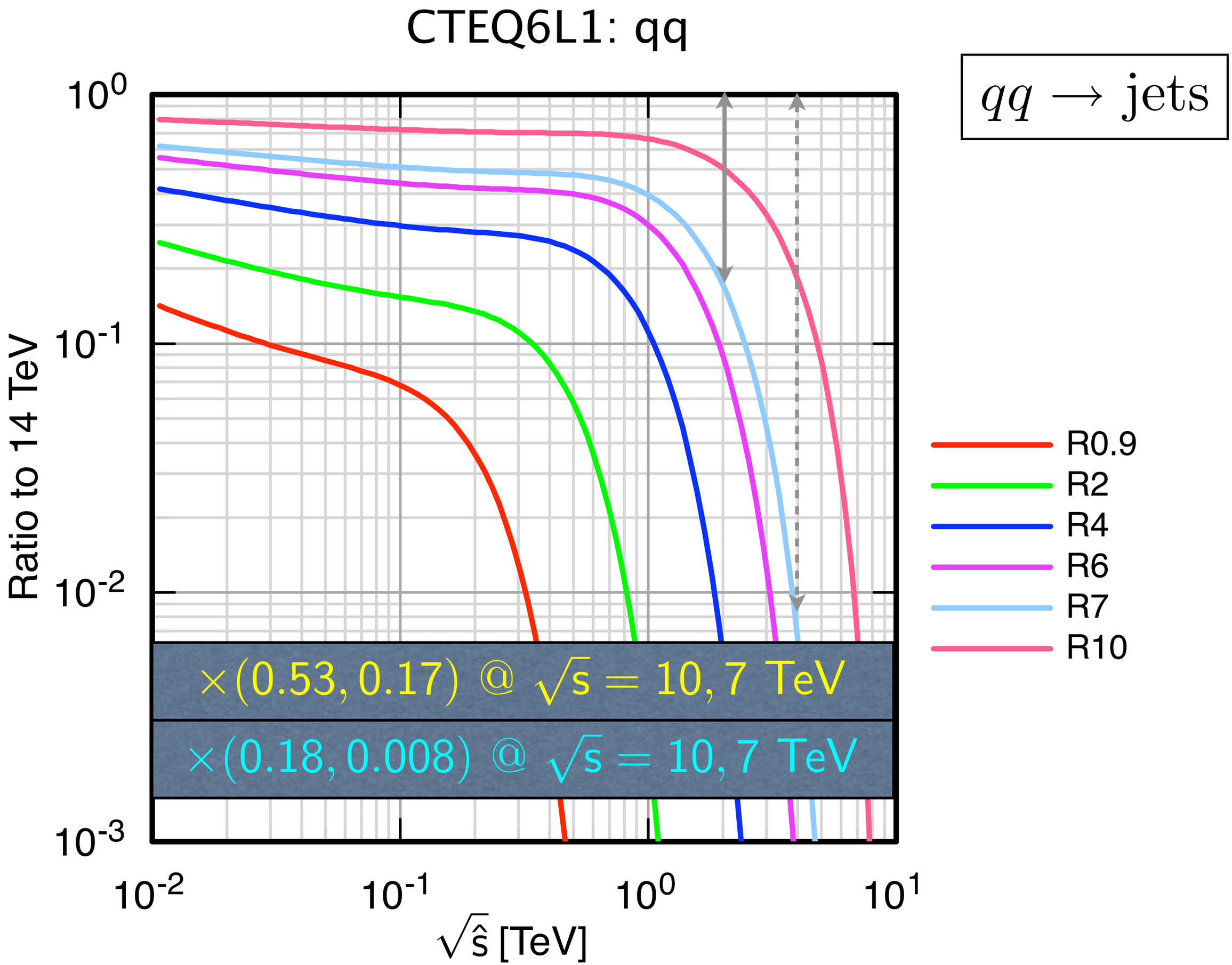

CTEQ6L1: gg
$gg \to H$
Ratio to Tevatron
10^3
10^2
10^1
10^0
10^{-1}
10^{-2}
$\times(30, 65, 100)$ @ $\sqrt{s} = 7, 10, 14$ TeV
$\approx$ Tevatron at $(200, 95, 45)$ pb^{-1}
10^{-2} $2*10^{-2}$
10^{-1} $2*10^{-1}$
10^0
$\sqrt{\hat{s}}$ [TeV]
R.9
R4
R6
R7
R10
R14

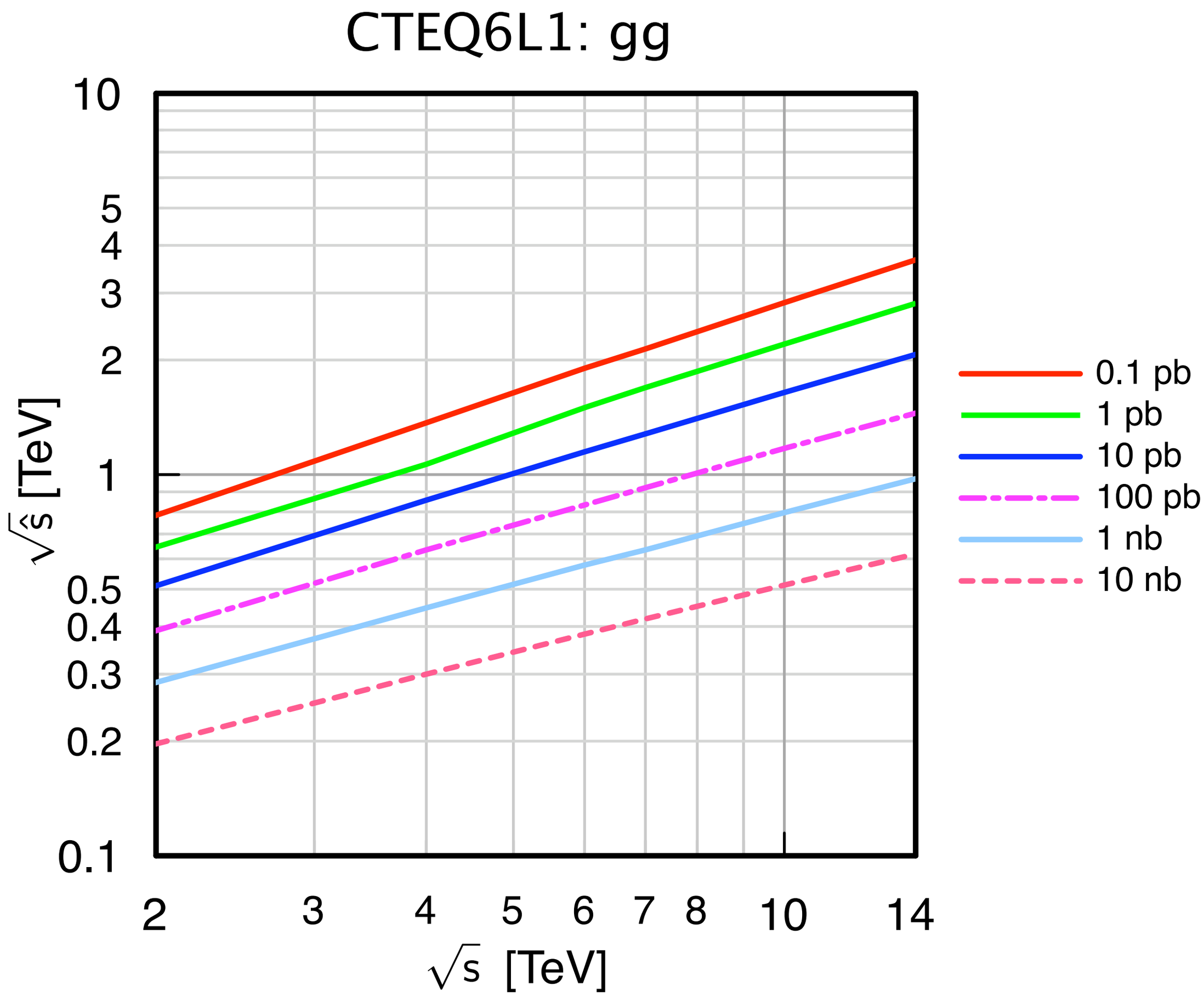

CTEQ6L1: $u\bar{d}$
$q\bar{q} \to VV$
Ratio to Tevatron
10^3
10^2
10^1
10^0
10^{-1}
10^{-2}
$\times(4.8, 7.3, 10.7)$ @ $\sqrt{s} = 7, 10, 14$ TeV
R0.9
R2
R4
R6
R7
R10
R14
10^{-2} $2*10^{-2}$
10^{-1} $2*10^{-1}$
10^0
$\sqrt{\hat{s}}$ [TeV]

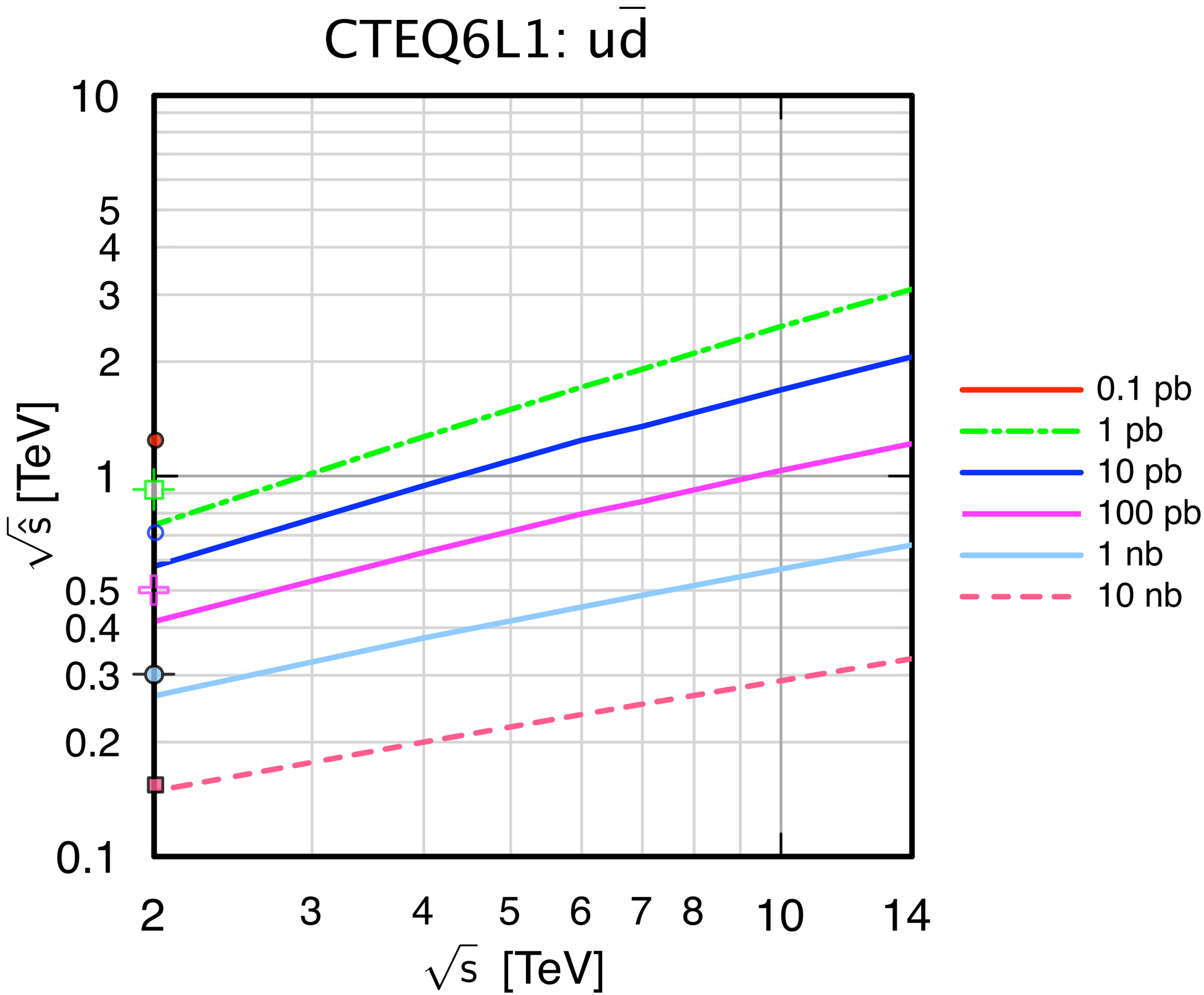

CTEQ6L1: $u\bar{d}$
$u\bar{d} \to W'$
Ratio to Tevatron
10^3
10^2
10^1
10^0
10^{-1}
10^{-2}
$\times(30, 70, 120)$ @ $\sqrt{s} = 7, 10, 14$ TeV
$\approx$ Tevatron at $(200, 90, 45)$ pb^{-1}
R0.9
R2
R4
R6
R7
R10
R14
10^{-2} $2*10^{-2}$
10^{-1} $2*10^{-1}$
10^0
$\sqrt{\hat{s}}$ [TeV]

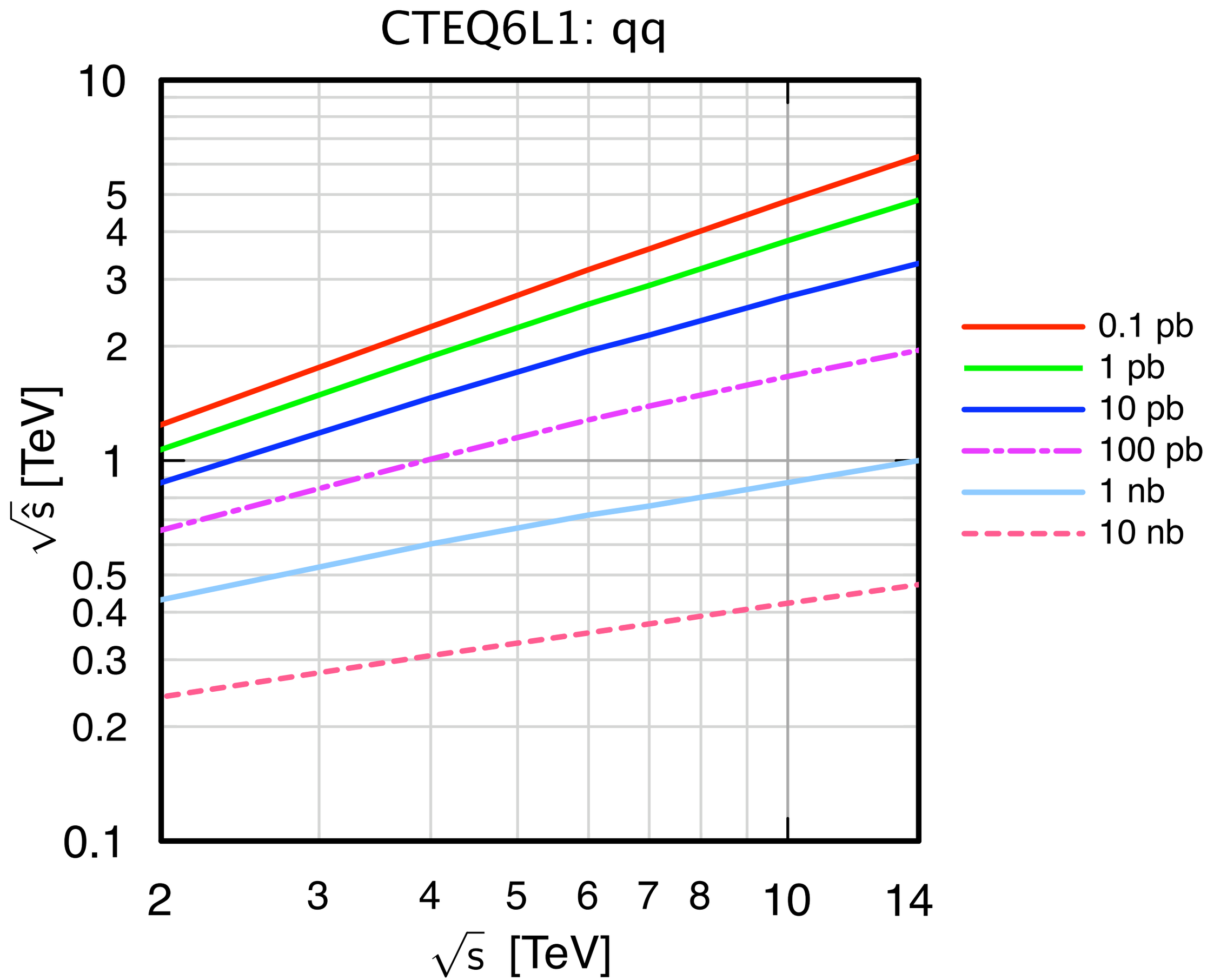

CTEQ6L1: $u\bar{d}$
$u\bar{d} \to W'$
Ratio to 14 TeV
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
$M_{W'} = 2$ TeV : $\div(3, 17)$ @ $\sqrt{s} = 10, 7$ TeV
10^{-2}
10^{-1}
10^{0}
10^{1}
$\sqrt{\hat{s}}$ [TeV]
R0.9
R2
RTev
R4
R6
R7
R10


CTEQ6L1: qq
$qq \to$ jets
Ratio to 2 TeV
10^3
10^2
10^1
10^0
10^{-1}
10^{-2}
$\times(135, 220, 340)$ @ $\sqrt{s} = 7, 10, 14$ TeV
$\approx$ Tevatron at $(44, 27, 18)$ pb^{-1}
R0.9
R4
R6
R7
R10
R14
10^{-2} $2*10^{-2}$
10^{-1} $2*10^{-1}$
10^0
$\sqrt{\hat{s}}$ [TeV]


CTEQ6L1: qq
$qq \to$ jets
Ratio to 14 TeV
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-2}
10^{-1}
10^0
10^1
$\sqrt{\hat{s}}$ [TeV]
R0.9
R2
R4
R6
R7
R10
$\times(0.53, 0.17)$ @ $\sqrt{s} = 10,7$ TeV
$\times(0.18, 0.008)$ @ $\sqrt{s} = 10,7$ TeV


CTEQ6L1: gg
10
5
4
3
2
1
0.5
0.4
0.3
0.2
0.1
$\sqrt{\hat{s}}$ [TeV]
2
3
4
5
6
7
8
10
14
$\sqrt{s}$ [TeV]
0.1 pb
1 pb
10 pb
100 pb
1 nb
10 nb


CTEQ6L1: $u\bar{d}$
10
5
4
3
2
1
0.5
0.4
0.3
0.2
0.1
$\sqrt{\hat{s}}$ [TeV]
2
3
4
5
6
7
8
10
14
$\sqrt{s}$ [TeV]
0.1 pb
1 pb
10 pb
100 pb
1 nb
10 nb


CTEQ6L1: qq
10
5
4
3
2
1
0.5
0.4
0.3
0.2
0.1
$\sqrt{\hat{s}}$ [TeV]
2
3
4
5
6
7
8
10
14
$\sqrt{s}$ [TeV]
0.1 pb
1 pb
10 pb
100 pb
1 nb
10 nb