

Gell-Mann Matrices

$R\bar{G}$ &
 GR

$$\lambda_1 = \begin{pmatrix} 0 & 1 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}$$

$$\lambda_2 = \begin{pmatrix} 0 & -i & 0 \\ i & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}$$

$$\lambda_3 = \begin{pmatrix} 1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & 0 \end{pmatrix}$$

$$\frac{1}{\sqrt{2}}(R\bar{R} - G\bar{G})$$

$R\bar{B}$ &
 $B\bar{R}$

$$\lambda_4 = \begin{pmatrix} 0 & 0 & 1 \\ 0 & 0 & 0 \\ 1 & 0 & 0 \end{pmatrix}$$

$$\lambda_5 = \begin{pmatrix} 0 & 0 & -i \\ 0 & 0 & 0 \\ i & 0 & 0 \end{pmatrix}$$

$$\lambda_6 = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 1 \\ 0 & 1 & 0 \end{pmatrix}$$

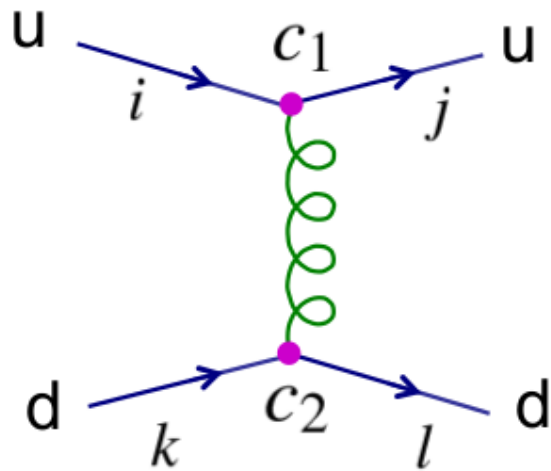
$$\lambda_7 = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & -i \\ 0 & i & 0 \end{pmatrix}$$

$$\lambda_8 = \frac{1}{\sqrt{3}} \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & -2 \end{pmatrix}$$

$G\bar{B}$ & $B\bar{G}$

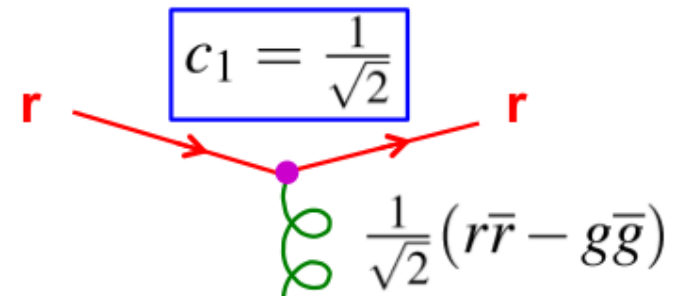
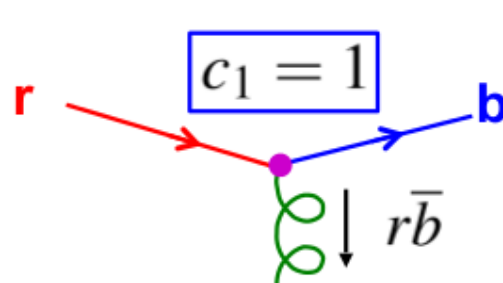
$$\frac{1}{\sqrt{6}}(R\bar{R} + G\bar{G} - 2B\bar{B})$$

Alternative Evaluation of Color Factors



$$C(ik \rightarrow jl) = \frac{1}{2}c_1c_2$$

color coefficients at the two vertices
depend on the quark and gluon colors

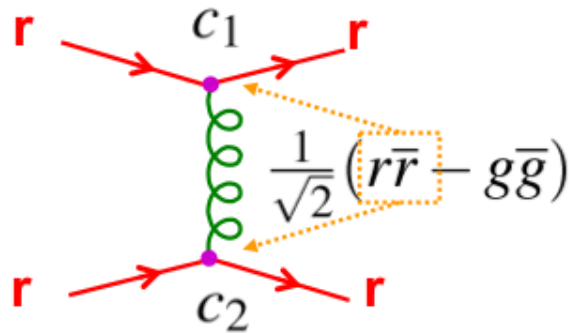


Sum over all possible exchanged gluons
conserving color at both vertices

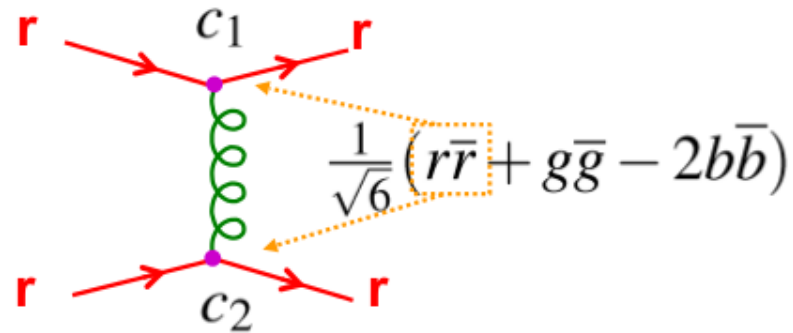
Alternative Evaluation of Color Factors

Ex. 1: $rr \rightarrow rr$; two possible exchanged gluons

$$C(rr \rightarrow rr) = \frac{1}{2} \left(\frac{1}{2} + \frac{1}{6} \right) = \frac{1}{3}$$

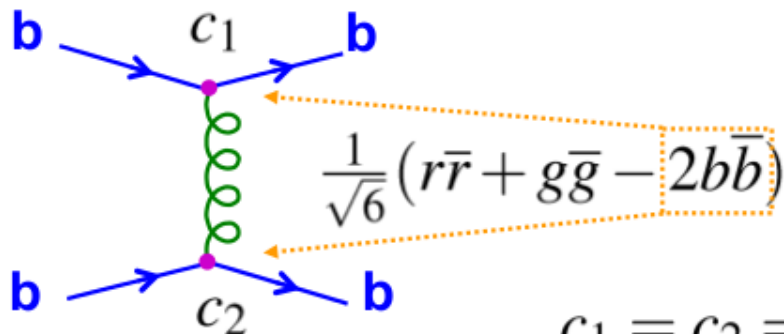


$$c_1 = c_2 = \frac{1}{\sqrt{2}}$$



$$c_1 = c_2 = \frac{1}{\sqrt{6}}$$

Ex. 2: $bb \rightarrow bb$; two possible exchanged gluons



$$c_1 = c_2 = -\frac{2}{\sqrt{6}}$$

$$C(bb \rightarrow bb) = \frac{1}{2} \left(\frac{2}{\sqrt{6}} \frac{2}{\sqrt{6}} \right) = \frac{1}{3}$$

Alternative Evaluation of Color Factors

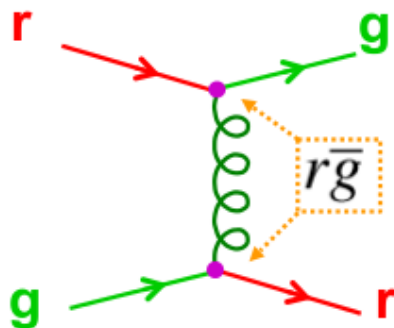
Ex. 3: $rb \rightarrow rb$; quarks don't change color

$c_1 = \frac{1}{\sqrt{6}}$
 $c_2 = -\frac{2}{\sqrt{6}}$

$\frac{1}{\sqrt{6}} (r\bar{r} + g\bar{g} - 2b\bar{b})$

$$C(rb \rightarrow rb) = \frac{1}{2} \left(-\frac{1}{\sqrt{6}} \frac{2}{\sqrt{6}} \right) = -\frac{1}{6}$$

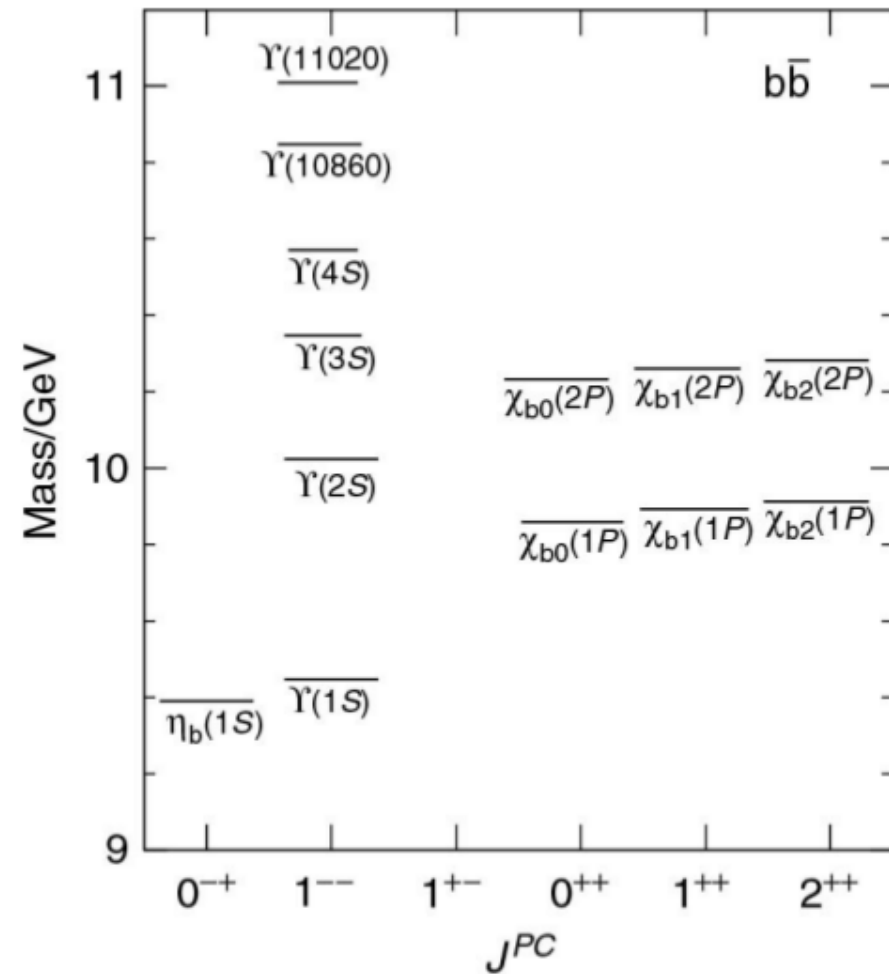
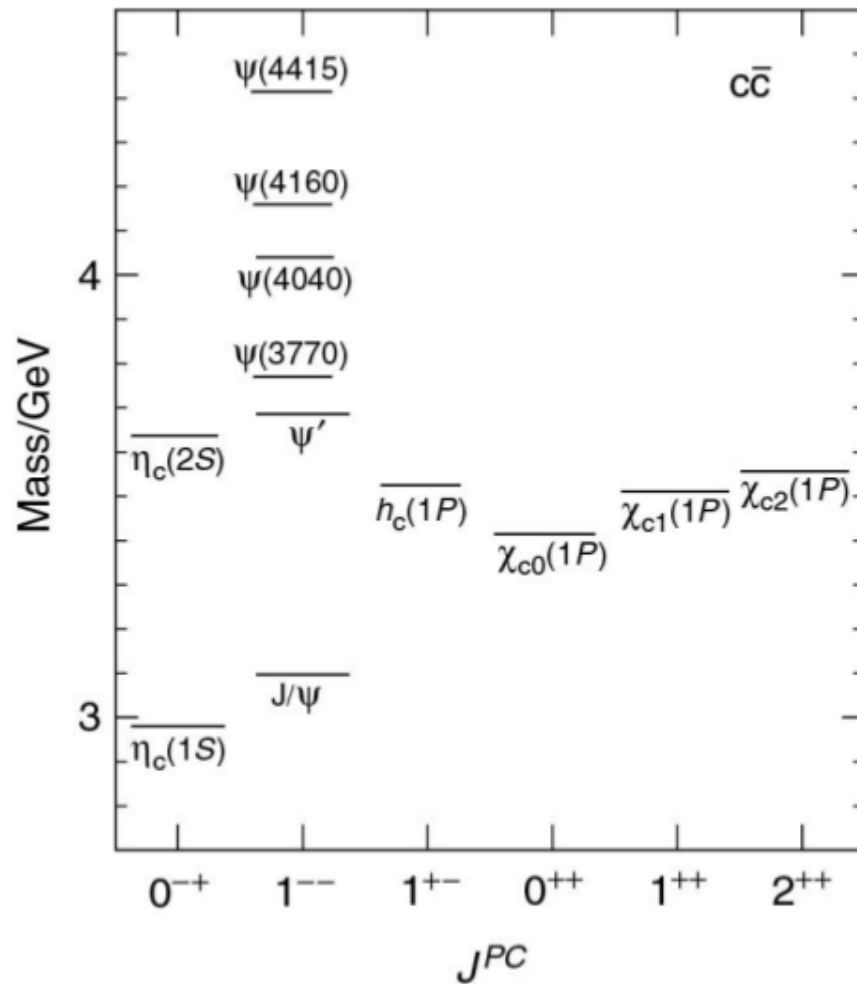
Ex. 2: $bb \rightarrow bb$; two possible exchanged gluons

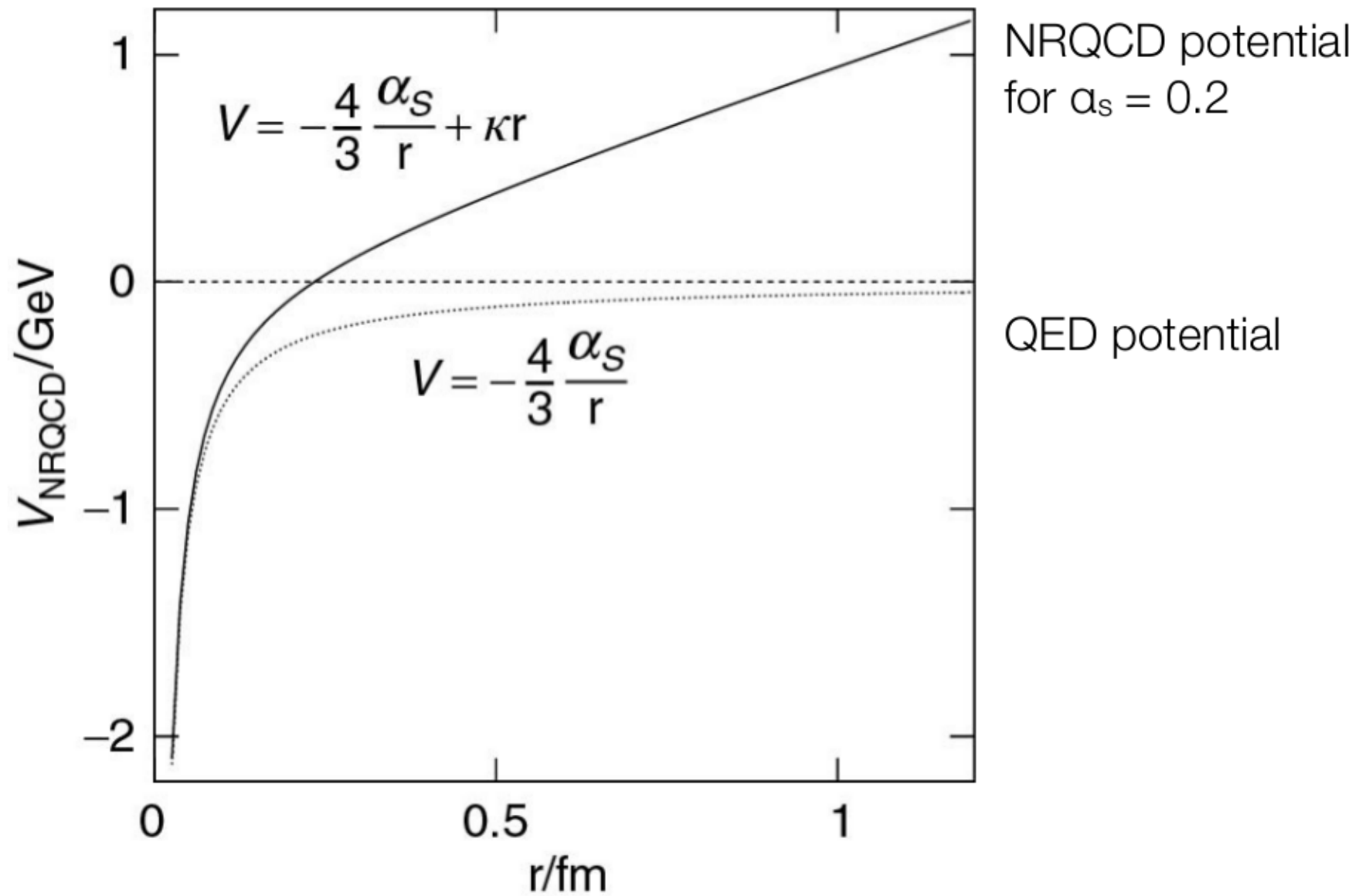


$$c_1 = c_2 = 1$$

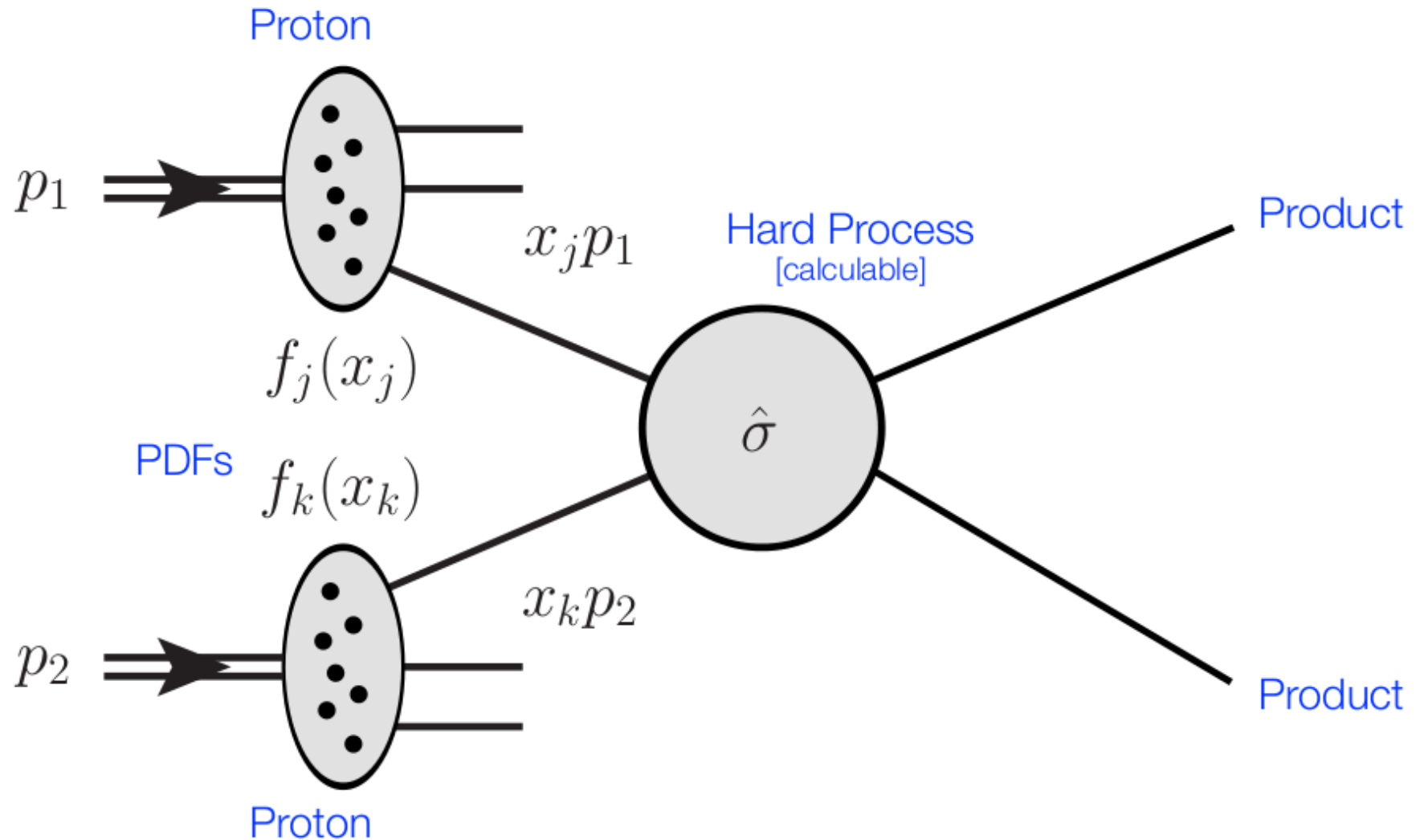
$$C(rg \rightarrow gr) = \frac{1}{2}$$

Charmonium und Bottonium States

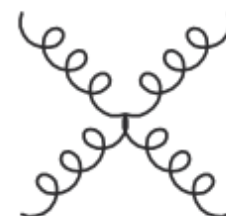
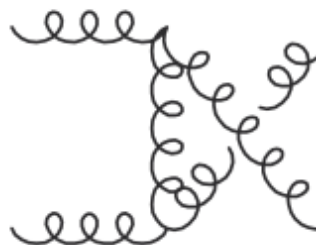
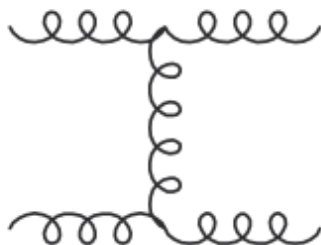
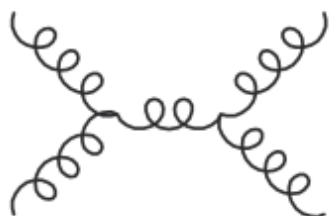
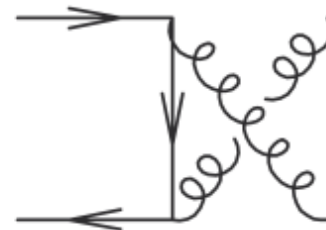
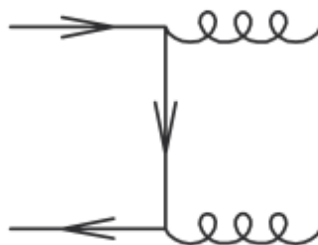
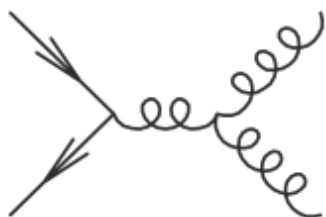
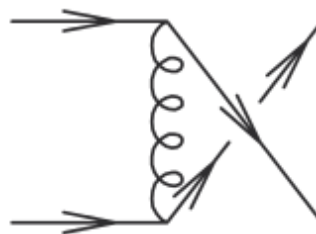
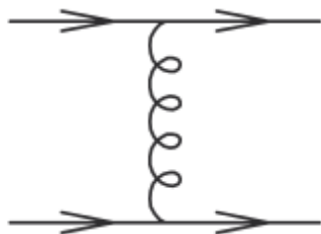




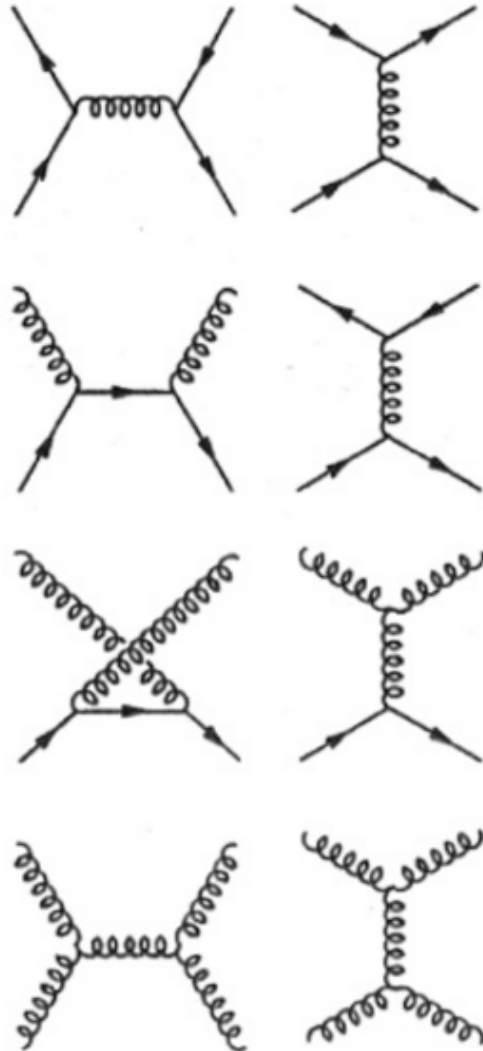
Proton-Proton Scattering @ LHC



Some Hard Processes ...

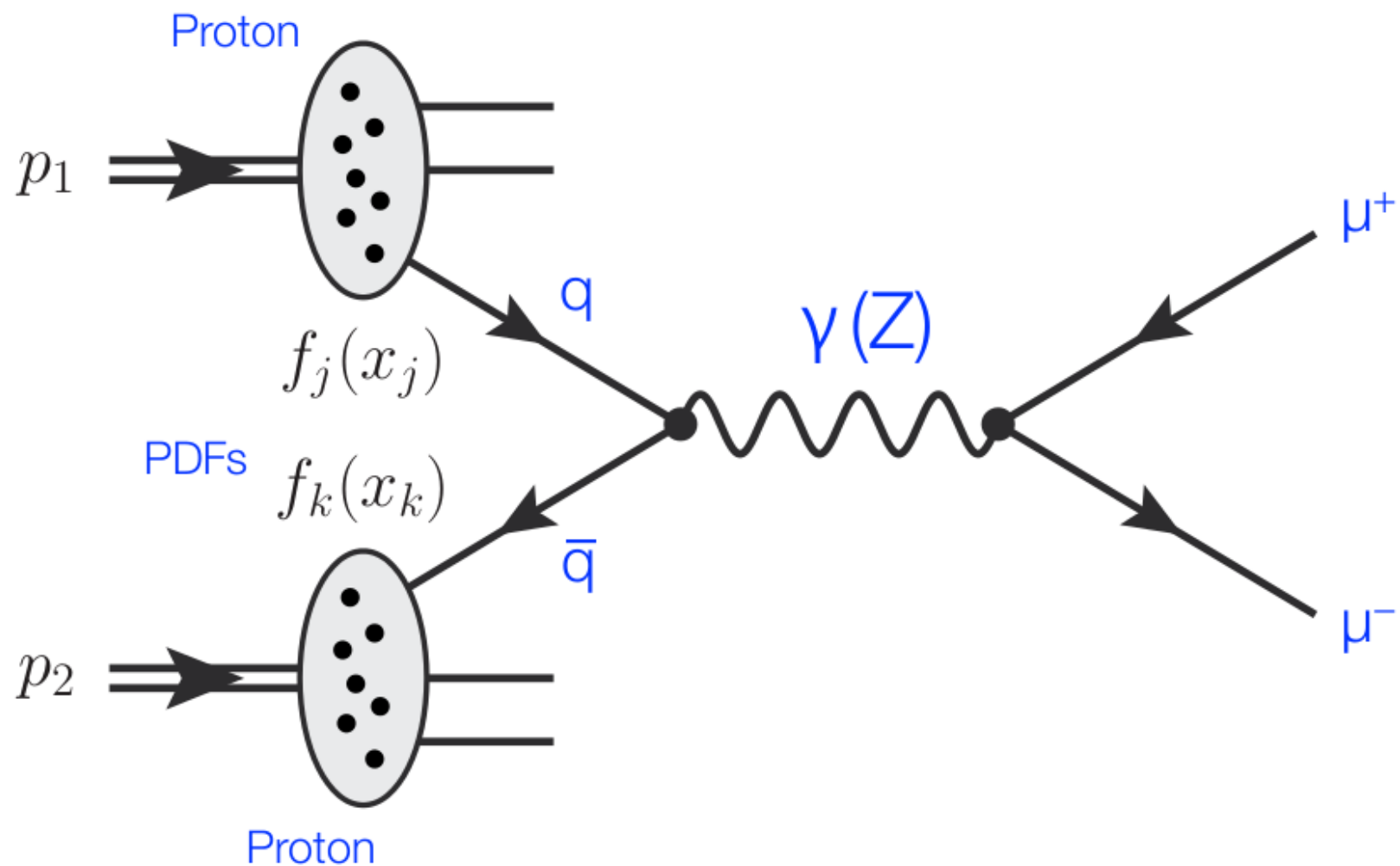


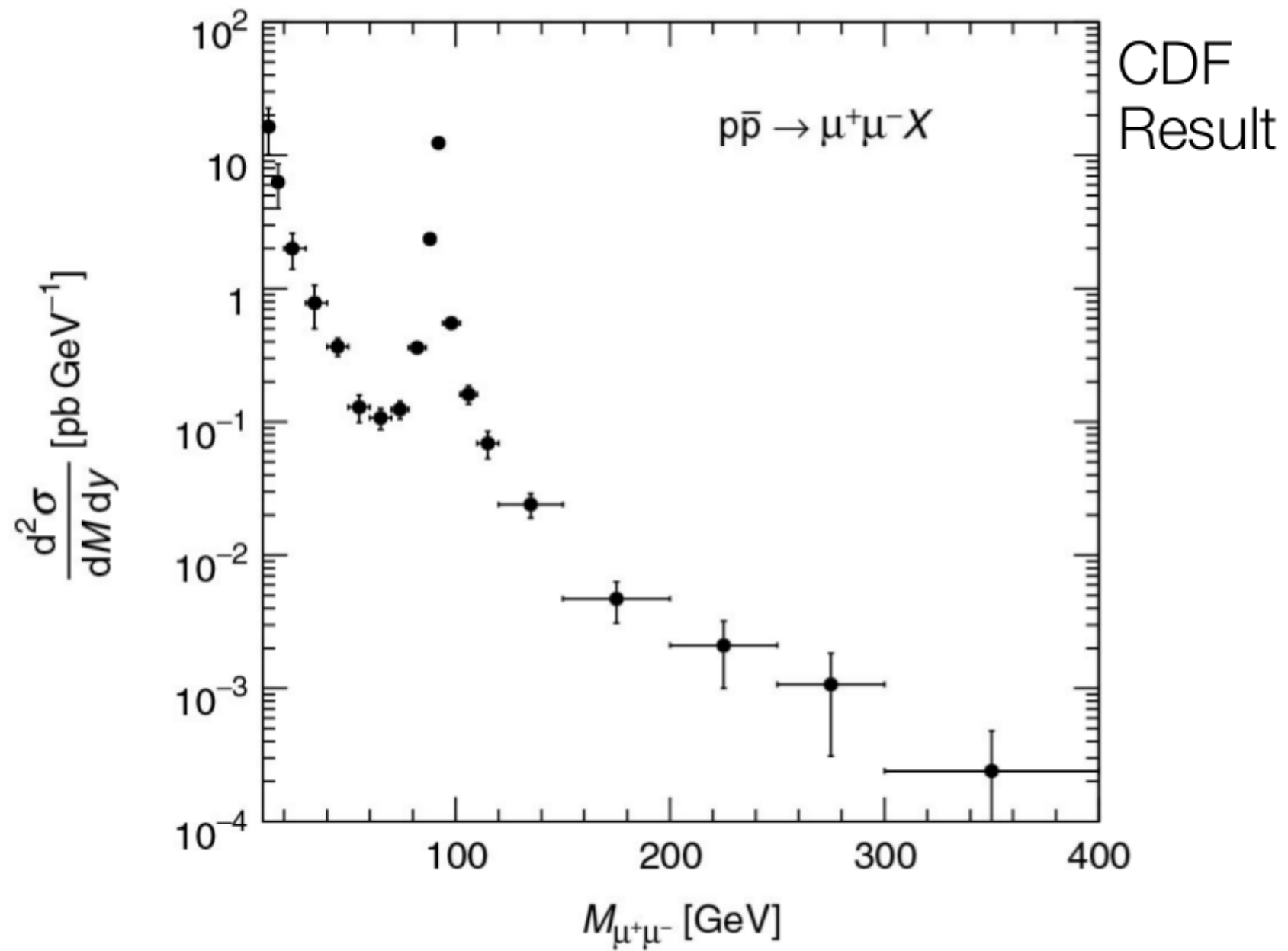
QCD Matrix Elements



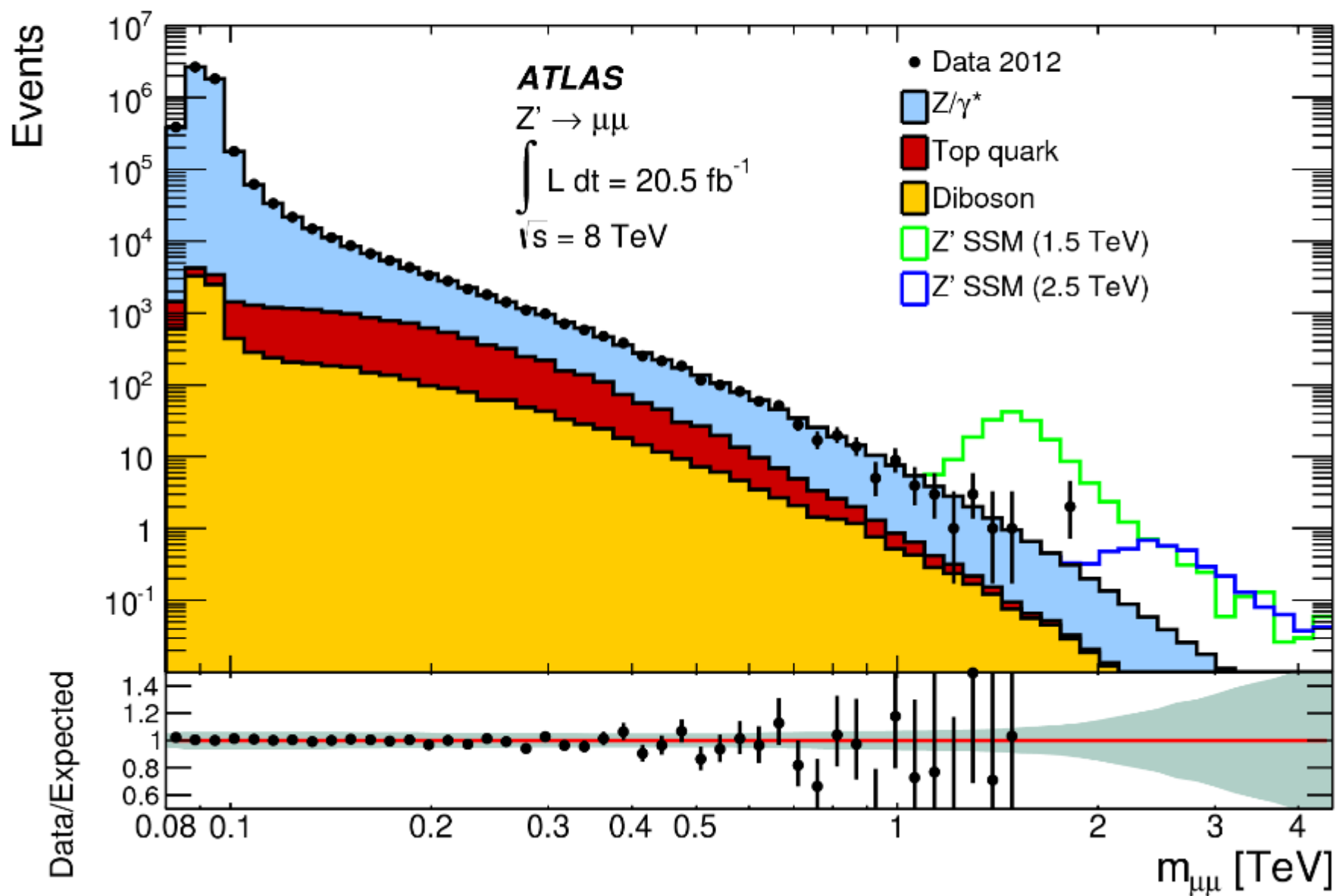
Subprocess	$ \mathcal{M} ^2/g_s^4$	$ \mathcal{M}(90^\circ) ^2/g_s^4$
$qq' \rightarrow qq'$ $q\bar{q}' \rightarrow q\bar{q}'$	$\frac{4}{9} \frac{\hat{s}^2 + \hat{u}^2}{\hat{t}^2}$	2.2
$qq \rightarrow qq$	$\frac{4}{9} \left(\frac{\hat{s}^2 + \hat{u}^2}{\hat{t}^2} + \frac{\hat{s}^2 + \hat{t}^2}{\hat{u}^2} \right) - \frac{8}{27} \frac{\hat{s}^2}{\hat{u}\hat{t}}$	3.3
$q\bar{q} \rightarrow q'\bar{q}'$	$\frac{4}{9} \frac{\hat{t}^2 + \hat{u}^2}{\hat{s}^2}$	0.2
$q\bar{q} \rightarrow q\bar{q}$	$\frac{4}{9} \left(\frac{\hat{s}^2 + \hat{u}^2}{\hat{t}^2} + \frac{\hat{t}^2 + \hat{u}^2}{\hat{s}^2} \right) - \frac{8}{27} \frac{\hat{u}^2}{\hat{s}\hat{t}}$	2.6
$q\bar{q} \rightarrow gg$	$\frac{32}{27} \frac{\hat{u}^2 + \hat{t}^2}{\hat{u}\hat{t}} - \frac{8}{3} \frac{\hat{u}^2 + \hat{t}^2}{\hat{s}^2}$	1.0
$gg \rightarrow q\bar{q}$	$\frac{1}{6} \frac{\hat{u}^2 + \hat{t}^2}{\hat{u}\hat{t}} - \frac{3}{8} \frac{\hat{u}^2 + \hat{t}^2}{\hat{s}^2}$	0.1
$qg \rightarrow qg$	$\frac{\hat{s}^2 + \hat{u}^2}{\hat{t}^2} - \frac{4}{9} \frac{\hat{s}^2 + \hat{u}^2}{\hat{u}\hat{s}}$	6.1
$gg \rightarrow gg$	$\frac{9}{4} \left(\frac{\hat{s}^2 + \hat{u}^2}{\hat{t}^2} + \frac{\hat{s}^2 + \hat{t}^2}{\hat{u}^2} + \frac{\hat{u}^2 + \hat{t}^2}{\hat{s}^2} + 3 \right)$	30.4

Example: Drell-Yan Process

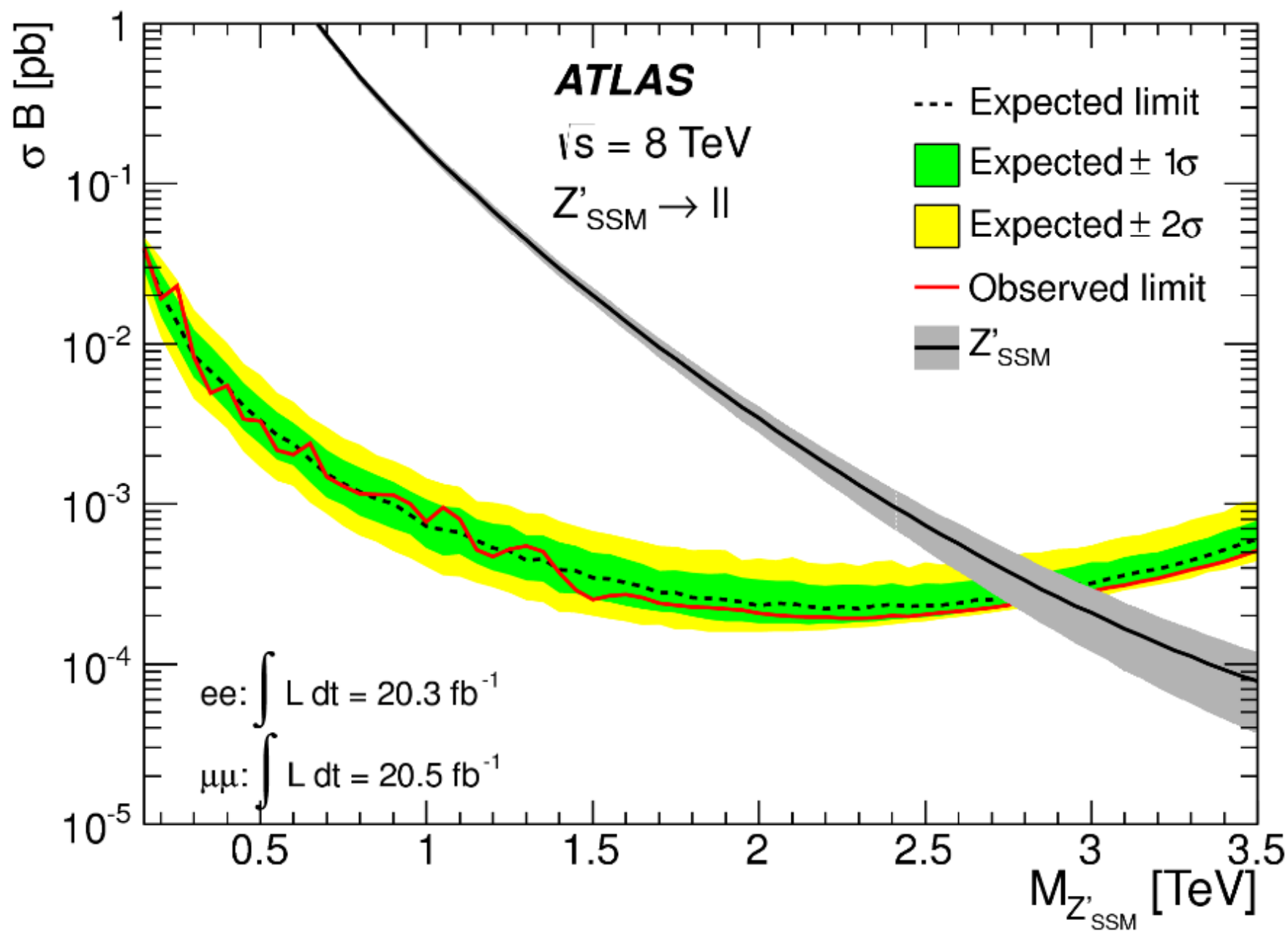




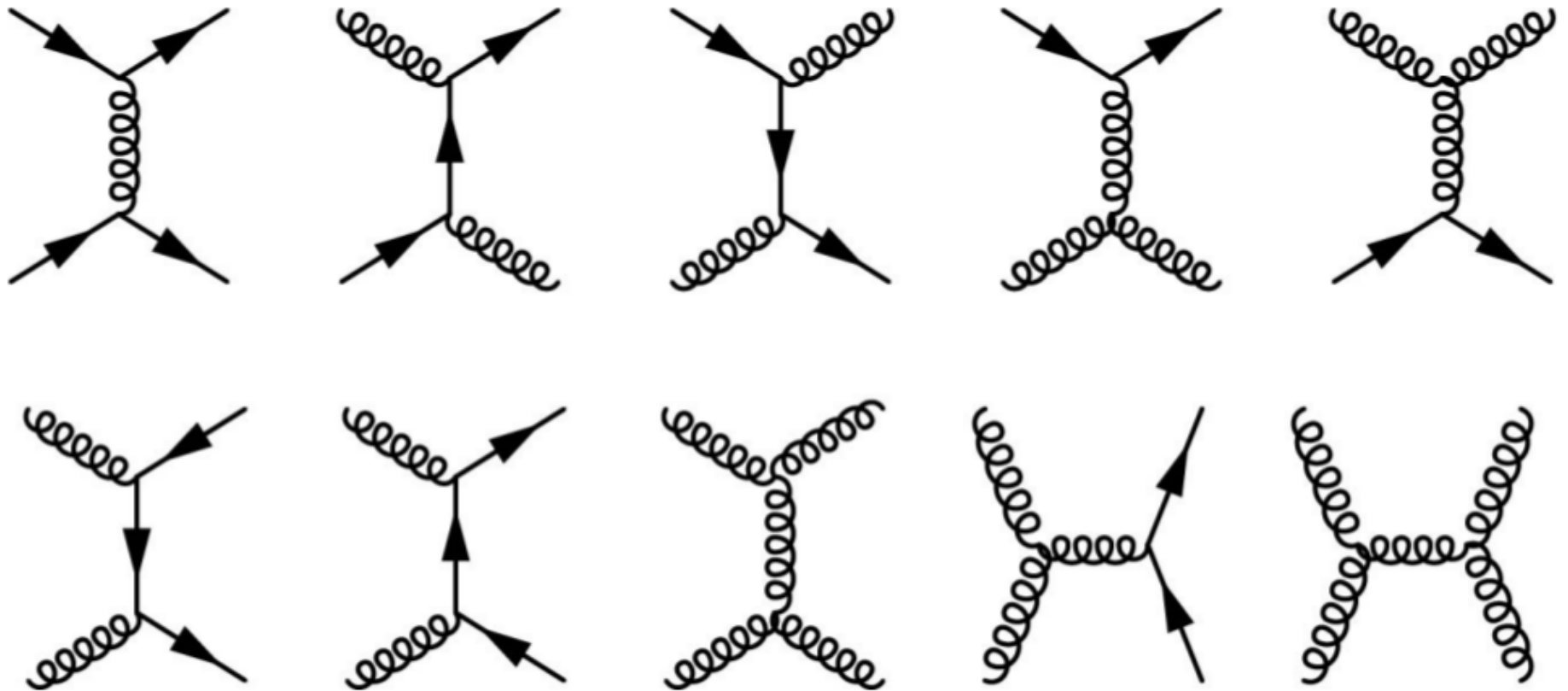
ATLAS Z' Search Result



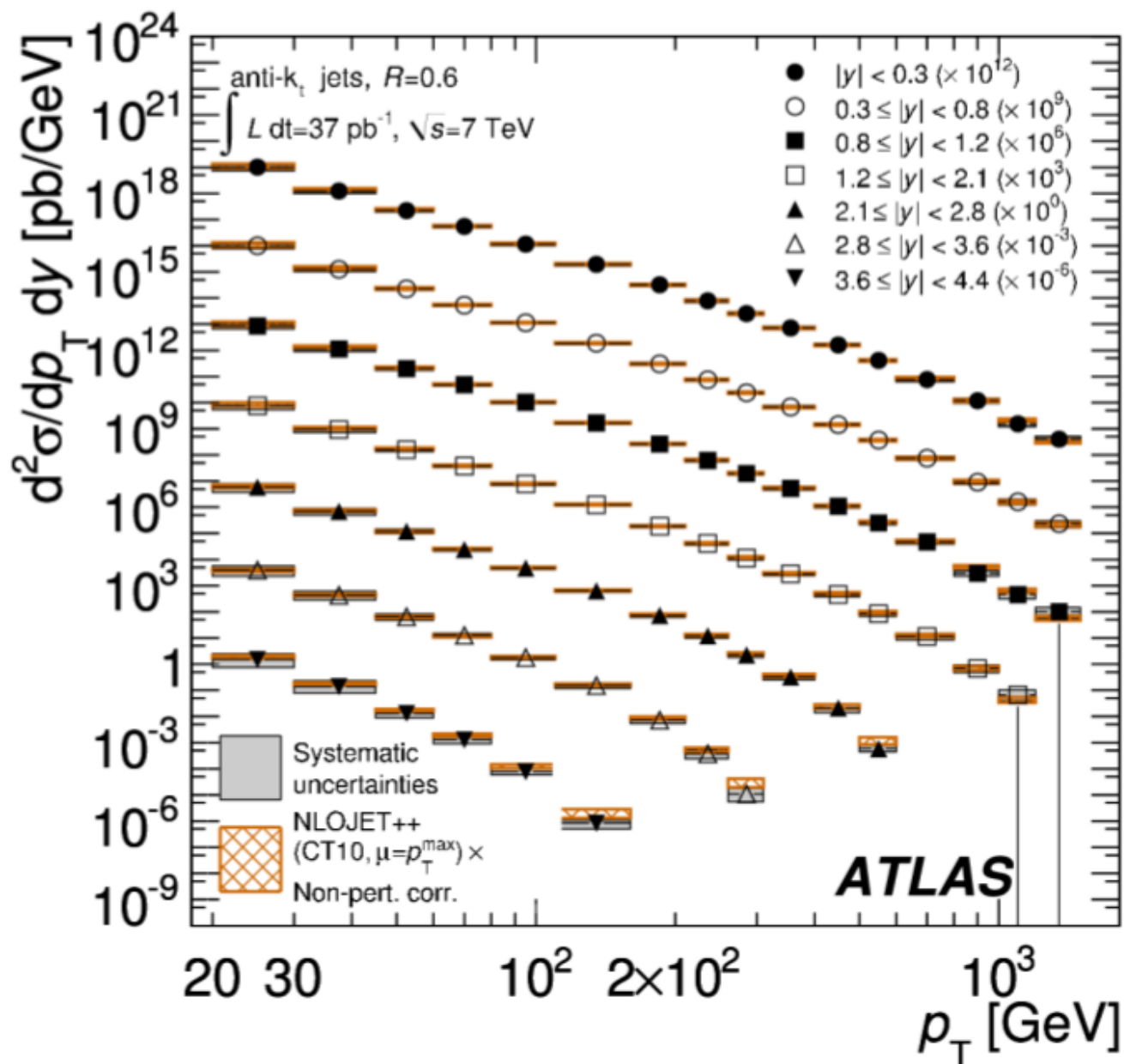
ATLAS Z' Search Result



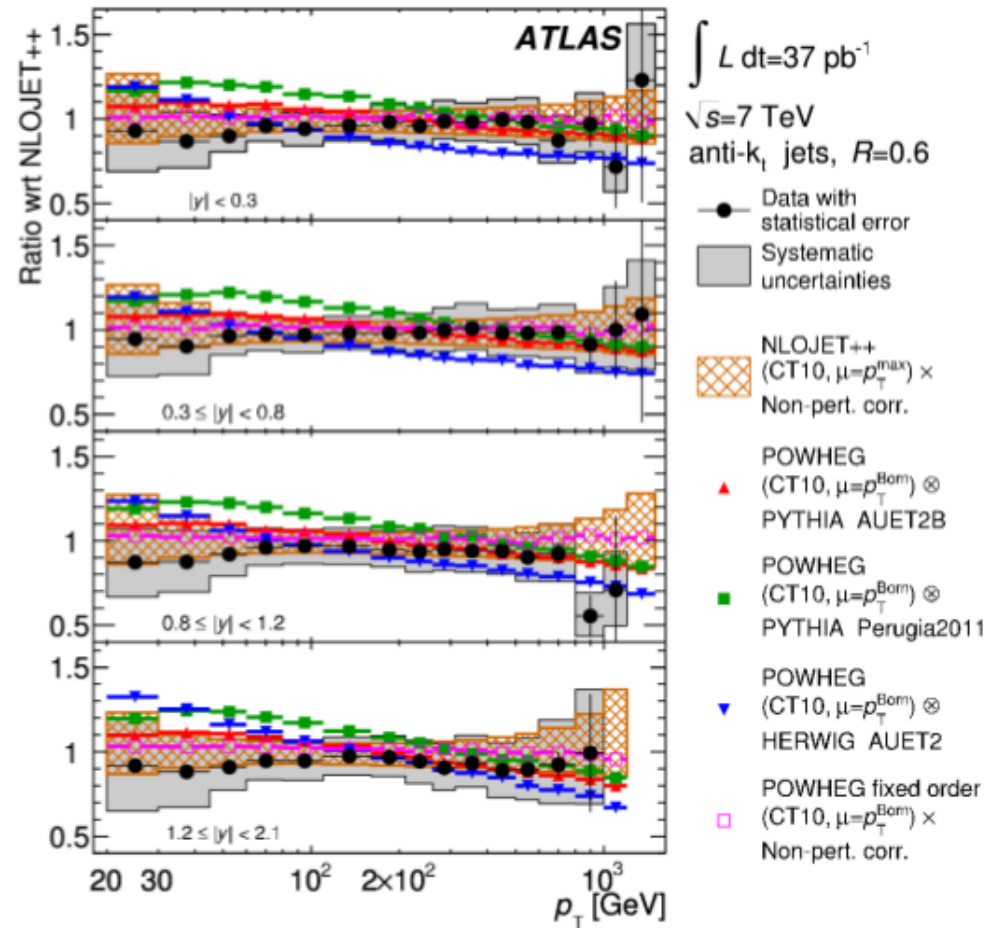
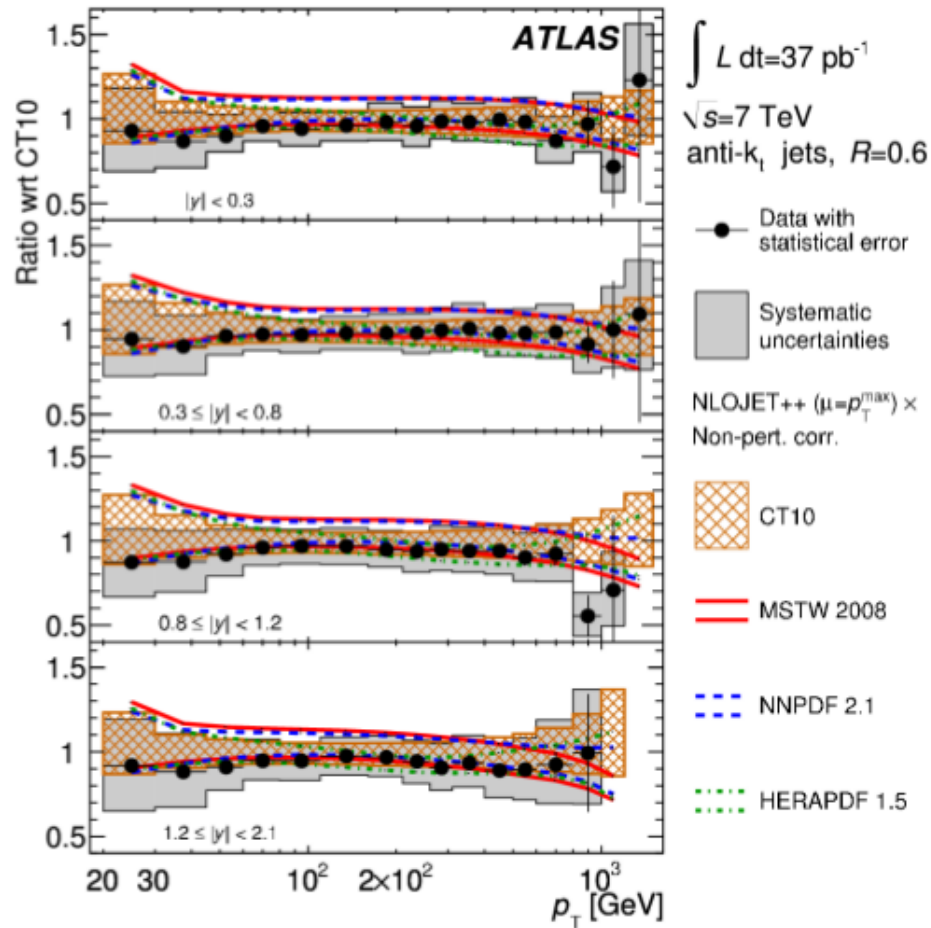
QCD Dijet-Production



Inclusive Jet Cross Section



Inclusive Jet Cross Section



Pseudorapidity Regions

