Multi Vector Boson Production via Gluon fusion @ LHC

Ambresh Shivaji
In collaboration with
Pankaj Agrawal

Institute of Physics, Bhubaneswar

September 26, 2011

Outline

- SM predictions at higher energies and TeV-scale physics.
- background counting for signal.
- large gluon luminosity at the LHC.

- We are interested in gluonic contribution to

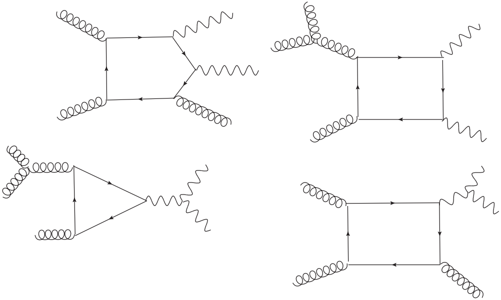
$$p + p \to V_1 + V_2 + g + X \quad (1)$$

at the LHC, where $V_1, V_2 \in (\gamma, Z, W)$.

- The inclusive cross-section is given by,

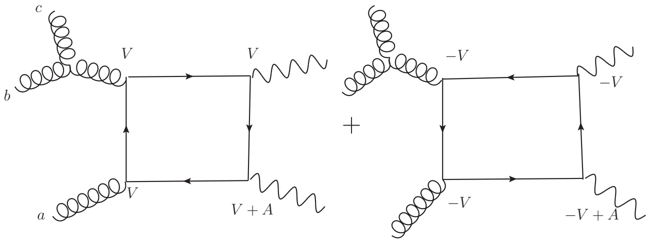
$$\sigma(p + p \to V_1 + V_2 + g + X) = \int_0^1 dx_1\, dx_2 \quad f_g(x_1) * f_g(x_2) * \hat{\sigma}(g + g \to V_1 + V_2 + g) \quad (2)$$

- At LO, these processes proceed via quark loop diagrams and can be put into following three general classes.

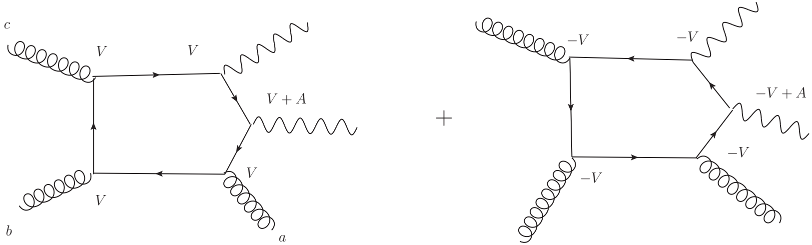


The wavy line represent any one of the $\gamma/Z/W$.

- structure of the $g + g \to g + Z + \gamma$, amplitude
  3×6, Box diagrams and 24, Penta diagrams.



$$\longrightarrow c_V f^{abc} B_V$$



$$\rightarrow (c_V f^{abc} P_V + c_A d^{abc} P_A)$$

- Thus the full amplitude has following general structure.

$$M^{abc}(gg \to gZ\gamma) = i\frac{f^{abc}}{2}M_V + \frac{d^{abc}}{2}M_A \quad (3)$$

$$M_V = P_V - B_V = \frac{e^2 g_s^3}{sin\theta_w cos\theta_w}[(\frac{7}{12} - \frac{11}{9}sin^2\theta_w)M_V^{(0)} + (\frac{1}{6} - \frac{4}{9}sin^2\theta_w)M_V^{(t)}] \quad (4)$$

$$M_A = P_A = (-)\frac{e^2 g_s^3}{sin\theta_w cos\theta_w}[\frac{7}{12}M_A^{(0)} + \frac{1}{6}M_A^{(t)}] \quad (5)$$

- We will focus on vector contribution only.

- Quark loop trace is calculated in FORM. The amplitude at this stage involves tensor integrals, 5-tensor penta-integral being the most complicated one.

$$E_{\mu\nu\rho\sigma\alpha} = \int \frac{d^n l}{(2\pi)^n} \frac{l_\mu l_\nu l_\rho l_\sigma l_\alpha}{D_0 D_1 D_2 D_3 D_4} \quad (6)$$

- Reduction of tensor integrals into appropriate scalars is done using methods of Oldenborgh and Vermaseren. Using Schouten Identity, we reduce penta-tensor and scalar integrals into lower rank box-tensor and scalar integrals.

$$E_0(0,1,2,3,4) = \sum_l c_l D_0^{(l)} + O(\epsilon) \quad (7)$$

(Z. Phys. C 46 (1990))

- After all above reductions, the amplitude has following general structure of any one loop amplitude in 4−dimensions.

$$M^{1-loop} = \sum_i d_i D_{0i} + \sum_i c_i C_{0i} + \sum_i b_i B_{0i} + \sum_i a_i A_{0i} + R \quad (8)$$

- Scalar Integrals with massless internal lines are evaluated analytically (up to D_0 with two massive external legs) following 't Hooft and Veltman. (Nucl. Phys. B 153, 365 (1979))
- Scalar integrals with massive internal lines are called from LoopTools.

- We regularize UV sing. in dimensional regularization while IR sing.(for massless quark contribution) are regularized by giving small mass to quarks in the loop.
- for massless quarks in the loop the amplitude looks,

$$M = M_{UV}\,\frac{1}{\epsilon_{UV}} + M_{IR^2}\,log^2(m_q^2) + M_{IR}\,log(m_q^2) + M_F \quad (9)$$

- For the massive quark contribution, 2^{nd} and 3^{rd} terms are absent.

- We have considered real polarization vecors for gauge bosons to compute the amplitude.
- Our processes being LO are expected to be UV as well as IR/ Collinear finite.

Divergence cancellation:

- *UV* cancellation ($M_{UV} = 0$):

  For both massive and massless quark contributions, we verify that Penta and the three classes of box amplitudes are separately UV finite.

- *IR* cancellation ($M_{IR^2} = M_{IR} = 0$):

  We verify that the amplitude is finite in $m_q \to 0$ limit. The IR/ collinear finiteness of the amplitude follows from the fact that each fermion loop diagram is collinear finite by itself.

Gauge Invariance :

- We have checked the gauge invariance of the vector part of the amplitude with respect to the γ, Z and all the three gluons. We do it numerically by replacing their polarizations with their respective 4-momenta.

- As one would expect the penta and three classes of box contributions are separately gauge invariant with respect to the γ and Z .
- For each gluon one of the three classes of box diagrams is gauge invariant and the cancellation takes place among penta and the other two box contributions.

Results:

- We present the preliminary result for the five massless quark contribution to the vector part of the amplitude.
- Cuts, Scales and Parameters:

$P_T(\gamma, Z, g) > 20 GeV$; $|\eta| < 2.5$

$\mu_F = E_T(Z)$;

$\sigma(fb)$ =

34.0044, $\sqrt{s} = 14 TeV$

10.0519, $\sqrt{s} = 7 TeV$

- It is important to account for all possible SM backgrounds at colliders.
- Gluon initiated SM processes are important at the LHC.
- Multi-vector bosons produced via gluon fusion can be important background to many new physics models in TeV-region.