Studies on aQGC in Wgg Channel at LHC

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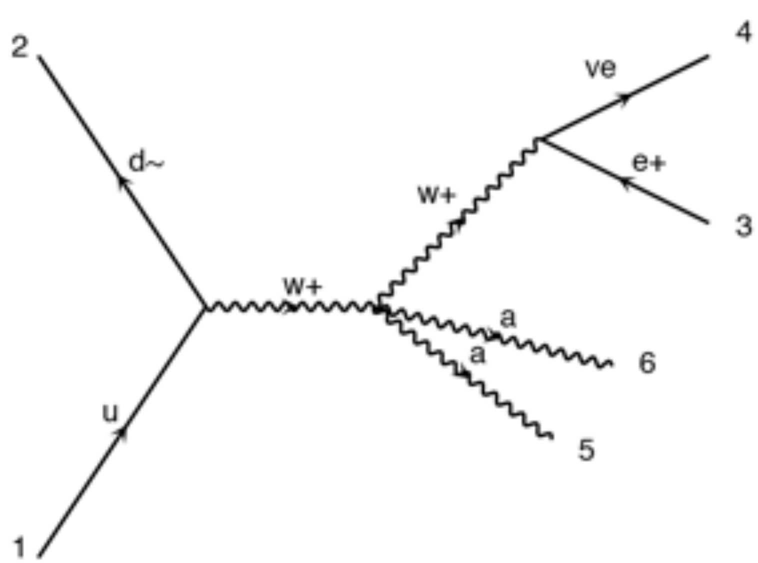
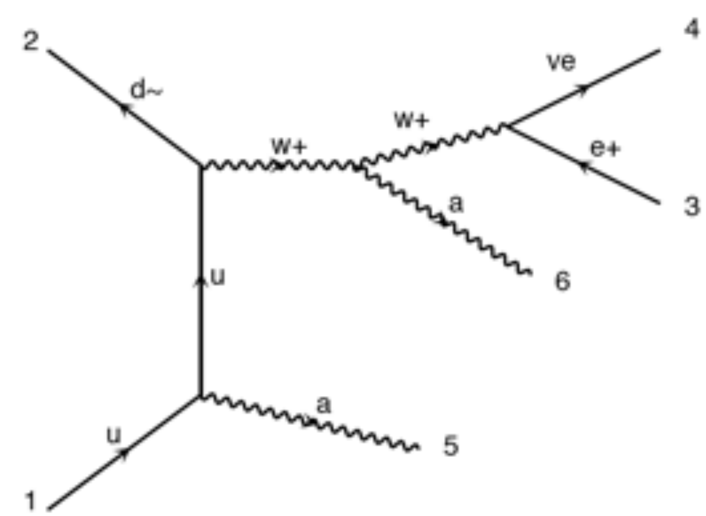
Introductions

- Wgg production contains contribution from quartic WWgg coupling which is the consequence of non-Abelian gauge structure of SM -> deviation from SM prediction is indication of aQGC.
- The cross section at 8 TeV is about a few fb per leptonic channel ->feasible to observe with current LHC data.
- Wgg can come from WWg TGC coupling + ISR or FSR photon -> good inclusive channel to detect anomaly in gauge couplings.

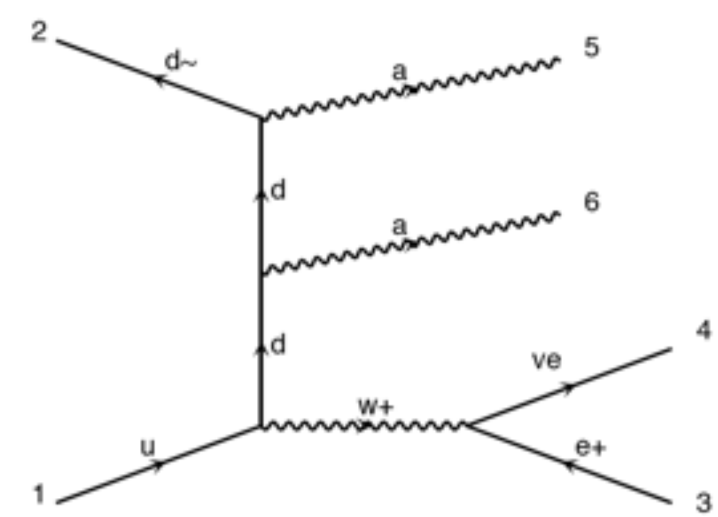
QGC



TGC

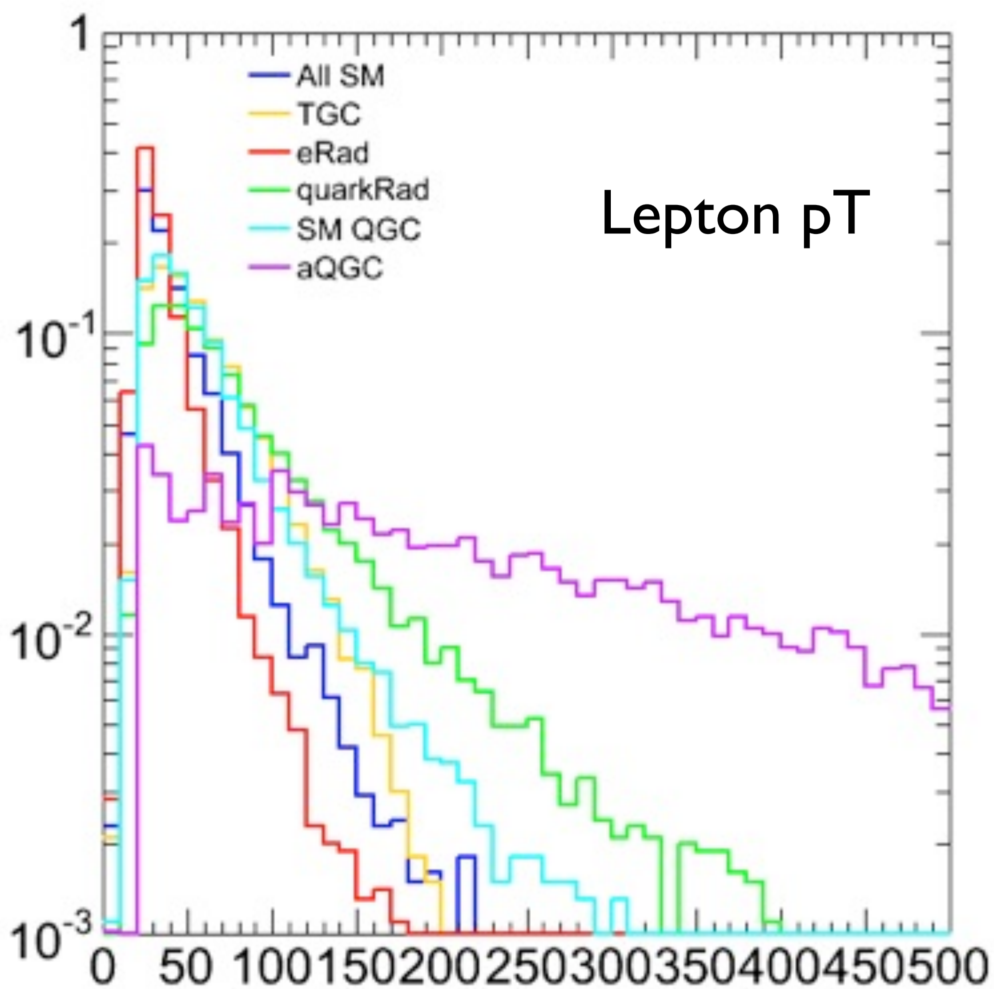


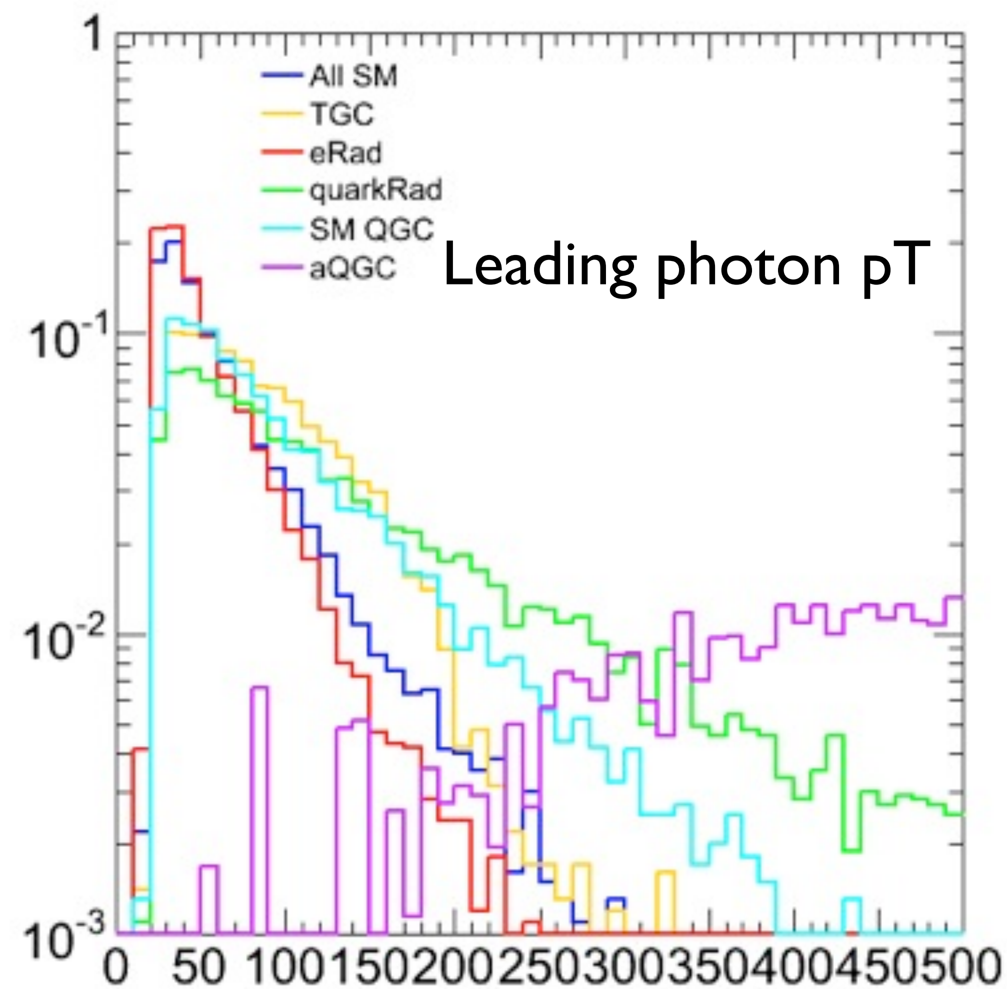
QCD W+2 photons production



SM QGC and Other Diagrams

- In SM, the contribution of QGC diagram is very small->rising the pT scale on final state object doesn't help.
- Probably some angular distributions, for example from radiation zero, can help to prove the existence of QGC -> require high statistic





Phenomenology aQGC at LHC

- Ref: Eur. Phys. J. C. 64 (2009), p. 25-33
- Dimension-6 effective Lagrangian framework

$$\mathcal{L}_6^0 = -\frac{e^2\beta_0}{16} F_{\mu\nu} F^{\mu\nu} \boldsymbol{W}^{\alpha} \cdot \boldsymbol{W}_{\alpha},$$

$$\mathcal{L}_6^c = -\frac{e^2\beta_c}{16} F_{\mu\alpha} F^{\mu\beta} \boldsymbol{W}^{\alpha} \cdot \boldsymbol{W}_{\beta}.$$

- 95% C.L. limits (14 TeV and assuming a jet rejection factor of 2000)

	β_0	β_c
10 fb^{-1}	$(-2.98, 3.28) \times 10^{-5}$	$(-5.00, 4.92) \times 10^{-5}$
30 fb^{-1}	$(-1.85, 2.19) \times 10^{-5}$	$(-3.19, 3.21) \times 10^{-5}$
100 fb^{-1}	$(-1.16, 1.50) \times 10^{-5}$	$(-2.03, 2.14) \times 10^{-5}$

- LEP limits (Phys. Rev. D 70, 032005 (2004)):

$$-0.020\ \text{GeV}^{-2} < a_0^W/\Lambda^2 < 0.020\ \text{GeV}^{-2} \qquad -0.052\ \text{GeV}^{-2} < a_c^W/\Lambda^2 < 0.037\ \text{GeV}^{-2}$$

Dimension-8 Effective Lagrangian

- General form of linearized effective Lagrangians

$$\mathcal{L}_{\text{eff}} = \frac{f_i}{\Lambda^n}\mathcal{O}_i^{n+4}$$

- Some operators which gives rise to the WWWW, WWZZ, WWAZ, WWAA, AAZZ, AZZZ, and ZZZZ vertices

$$\mathcal{L}_{M,0} = \text{Tr}\left[\hat{W}_{\mu\nu}\hat{W}^{\mu\nu}\right] \times \left[(D_\beta\Phi)^\dagger D^\beta\Phi\right] \quad (8)$$

$$\mathcal{L}_{M,1} = \text{Tr}\left[\hat{W}_{\mu\nu}\hat{W}^{\nu\beta}\right] \times \left[(D_\beta\Phi)^\dagger D^\mu\Phi\right] \quad (9)$$

$$\mathcal{L}_{M,2} = \left[B_{\mu\nu}B^{\mu\nu}\right] \times \left[(D_\beta\Phi)^\dagger D^\beta\Phi\right] \quad (10)$$

$$\mathcal{L}_{M,3} = \left[B_{\mu\nu}B^{\nu\beta}\right] \times \left[(D_\beta\Phi)^\dagger D^\mu\Phi\right] \quad (11)$$

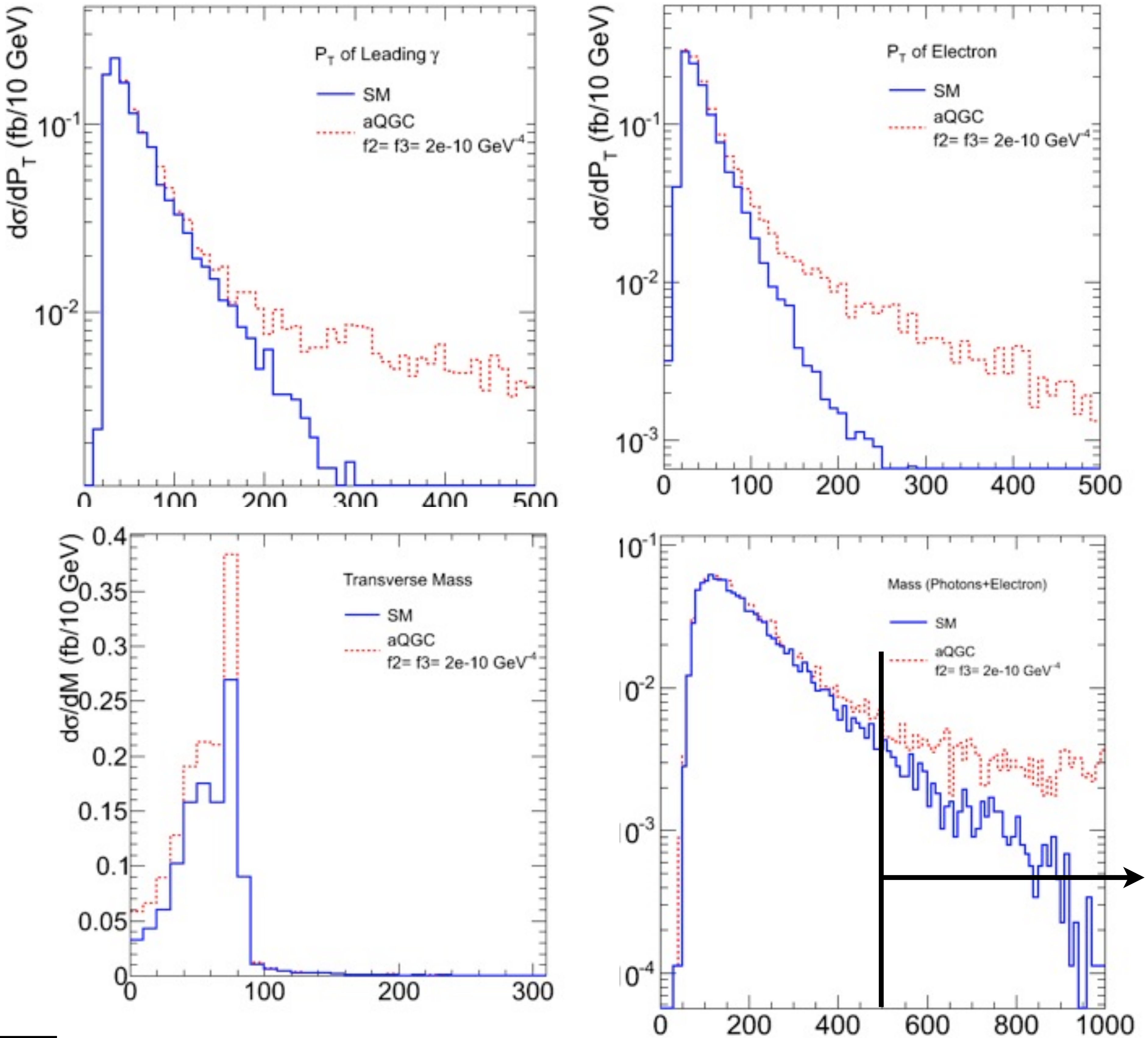
- Two MC generators implemented this theory frameworks
  - FeynRules http://feynrules.irmp.ucl.ac.be/wiki/AnomalousGaugeCoupling
    - UFO models for LHC available to interface with Madgraph generator +Delphes or PGS
    - LO cross sections currently
  - VBFNLO: NLO calculator for pp collider only, LHA event files available at LO

LO Cross Section From Magraph

- Estimate LO cross section for pp->W+,g,g W+ -> e+, neu
- Fiducial definition
  - pT (electron, g) > 20 GeV
  - |eta (electron, g)| < 2.5
  - dR(g,g) > 0.4
  - dR(e,g) > 0.7
- Use aQGC models with LM2 and LM3 operators
  - F2 ~ $a_0/(\Lambda^2 * \langle V \rangle^2)$, $\langle V \rangle$=250 GeV when compared to dimension-6 Lagrangian
  - F3 ~ $a_C/(\Lambda^2 * \langle V \rangle^2)$

Cross section	W(e+,nu) g g (fb)	W(e+,nu) g jet (pb)	F2=F3=2e-10 GeV (fb)	F2=F3=-2e-10 GeV (fb)
8 TeV	1.127±0004	1.168±0.004	1.461±0.003	1.416±0.004
13 TeV	1.510±0.005	1.887±0.006	3.689±0.007	3.587±0.007

Kinematic Plots



aQGC is sensible at high scale

Signal region for a counting experiment

Expected Limits at 8 TeV

- Perform counting experiment and find the expected cross section limits
  - Total mass of electron and photons distribution is used to count number of events
  - Signal region m(electron, g, g) > 500 GeV
  - Cross section limits are derived using Bayesian approach with Poisson statistic

$$\beta = \int_0^{\sigma_{\mathrm{UL}}} d\sigma \, \rho(\sigma | k, I) \; .$$

- Inputs:

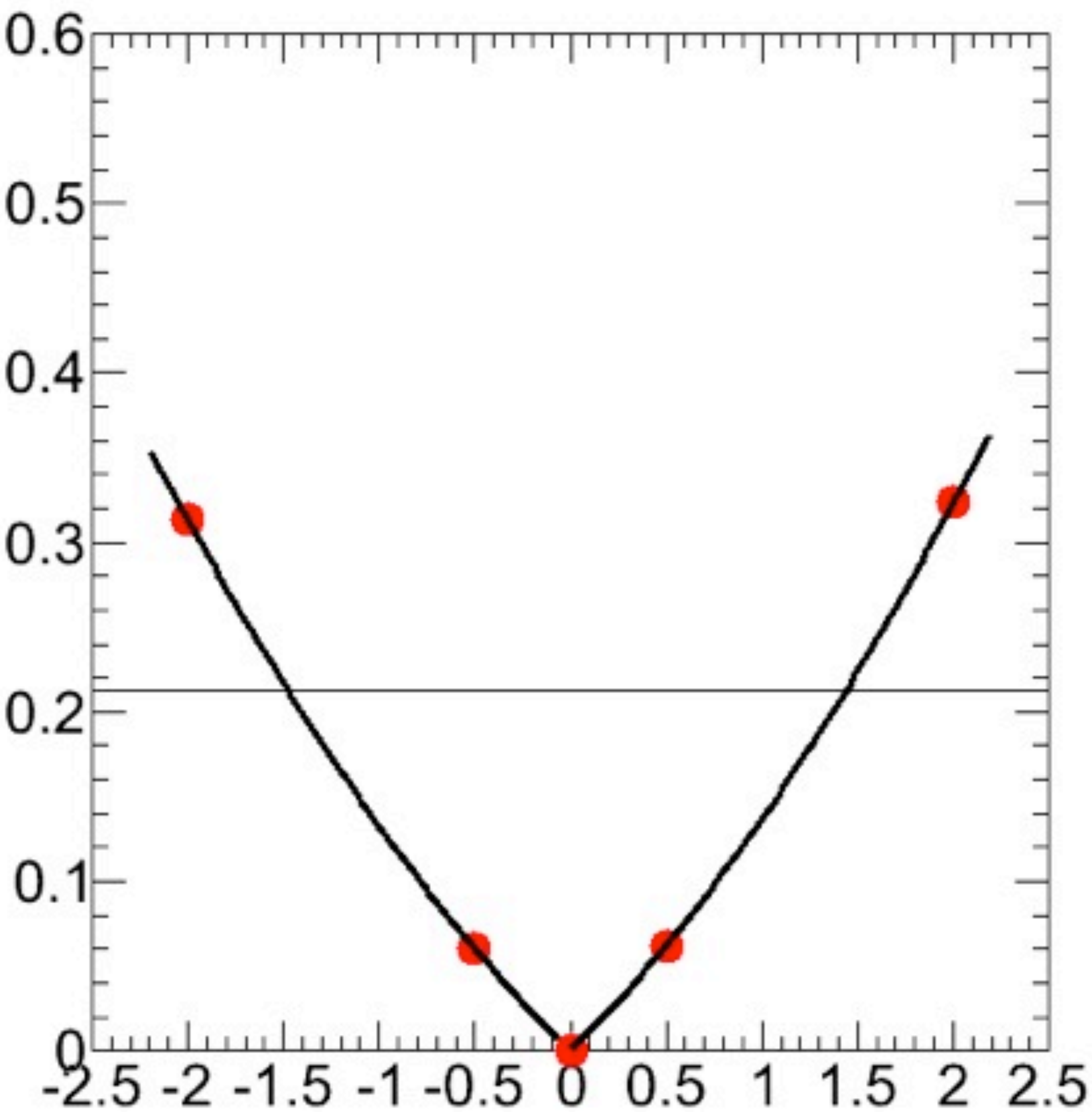
Lumi	Lumi Err	Selection Efficiency	Selection efficiency error	Background	Background Error
22 ivn. fb	4%	73%	5%	~1.54	10%

Cross section limits within fiducial definition: 0.212 fb

Limits on F2

- Simplified 1D limit setting for F2
  - Set F3 = 0 and find the cross section in fiducial cuts as a function of F2

F2 ~ [-1.5e-10,1.5e-10] GeV^{-4}



- Expect that limits on F parameters are in the range ~ 10^{-10} GeV^{-4} at 8 TeV with current LHC data

Summary

- W+gamma gamma is a good channel to perform early/preliminary studies on the aQGC at LHC.
- The aQGC parameters in effective Lagrangian can be constrained by order of two or tree tighter than LEP limits using current 8 TeV LHC data.
- The workflow from aQGC model->Madgraph->Delphes is pretty straight forward -> extent the studies to higher LHC energy scenario.