國科大杭州高等研究院
Hangzhou Institute for Advanced Study, UCAS

LHC Probes of the Quartic Couplings of Gluons to Photons and Z Bosons

Kai MA (马凯)

In collaboration with John ELLIS and Shao-Feng GE

(The paper will appear on arXiv soon)

Hangzhou Institute for Advanced Study, UCAS
International Centre for Theoretical Physics Asia-Pacific

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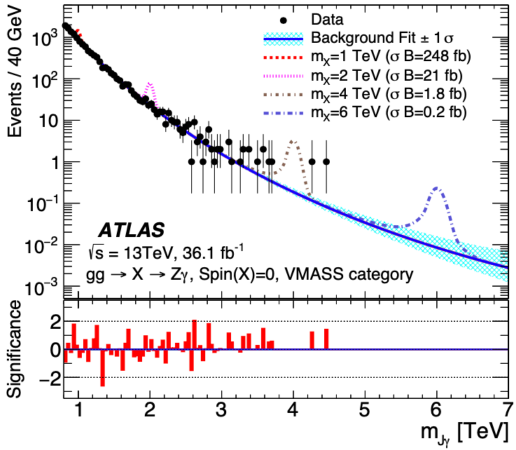
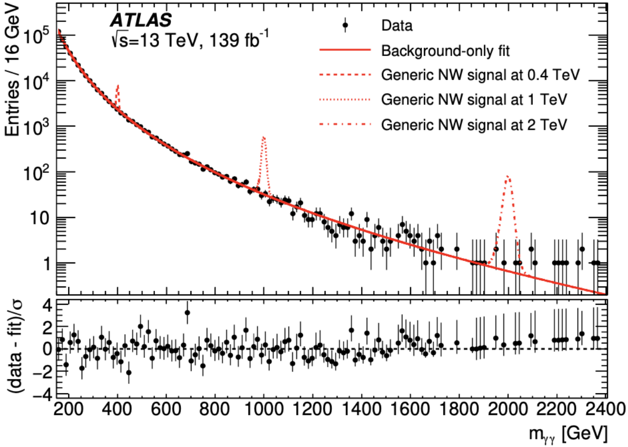
Motivations

1. In the SM the quartic couplings are fixed by gauge invariance.
2. New physics can be systematically described by SMEFT.
3. $(\mathcal{O} \text{ of D-6})^2 \sim (\mathcal{O} \text{ of SM}) \times (\mathcal{O} \text{ of D-8})$
4. Systematic separation of quadratic D-6 effects and linear D-8 effects is quite challenging.
5. The simplest processes are that do not receive D-6 contributions (at tree level). For instance: $\gamma\gamma \to \gamma\gamma$
6. Here we studying $gg \to \gamma\gamma$, $gg \to z(\ell^+\ell^-, \nu\bar{\nu}, q\bar{q})\,\gamma$.

ATLAS & CMS Searches: Heavy Resonance



arXiv:1805.01908



arXiv:2102.13405

Dimension-8 gQGC Operators

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$SU(3)$ and $SU(2)$ gauge fields

$$
\begin{aligned}
\mathcal{L}_{gT,0} &= \frac{F_{gT,0}}{16} \sum_a \hat{G}^a_{\mu\nu} \hat{G}^{a,\mu\nu} \times \sum_i \hat{W}^i_{\alpha\beta} \hat{W}^{i,\alpha\beta} \,, \\
\mathcal{L}_{gT,1} &= \frac{F_{gT,1}}{16} \sum_a \hat{G}^a_{\alpha\nu} \hat{G}^{a,\mu\beta} \times \sum_i \hat{W}^i_{\mu\beta} \hat{W}^{i,\alpha\nu} \,, \\
\mathcal{L}_{gT,2} &= \frac{F_{gT,2}}{16} \sum_a \hat{G}^a_{\alpha\mu} \hat{G}^{a,\mu\beta} \times \sum_i \hat{W}^i_{\nu\beta} \hat{W}^{i,\alpha\nu} \,, \\
\mathcal{L}_{gT,3} &= \frac{F_{gT,3}}{16} \sum_a \hat{G}^a_{\alpha\mu} \hat{G}^a_{\beta\nu} \times \sum_i \hat{W}^{i,\mu\beta} \hat{W}^{i,\nu\alpha} \,,
\end{aligned}
$$

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$$\mathcal{L}_{gT,1} = \frac{F_{gT,1}}{16} \sum_a \hat{G}^a_{\alpha\nu} \hat{G}^{a,\mu\beta} \times \sum_i \hat{W}^i_{\mu\beta} \hat{W}^{i,\alpha\nu} ,$$

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$SU(3)$ and $U(1)$ gauge fields

$$\mathcal{L}_{gT,4} = \frac{F_{gT,4}}{16} \sum_a \hat{G}^a_{\mu\nu} \hat{G}^{a,\mu\nu} \times B_{\alpha\beta} B^{\alpha\beta} ,$$

$$\mathcal{L}_{gT,5} = \frac{F_{gT,5}}{16} \sum_a \hat{G}^a_{\alpha\nu} \hat{G}^{a,\mu\beta} \times B_{\mu\beta} B^{\alpha\nu} ,$$

$$\mathcal{L}_{gT,6} = \frac{F_{gT,6}}{16} \sum_a \hat{G}^a_{\alpha\mu} \hat{G}^{a,\mu\beta} \times B_{\nu\beta} B^{\alpha\nu} ,$$

$$\mathcal{L}_{gT,7} = \frac{F_{gT,7}}{16} \sum_a \hat{G}^a_{\alpha\mu} \hat{G}^a_{\beta\nu} \times B^{\mu\beta} B^{\nu\alpha} .$$

Dimension-8 gQGC Operators

$SU(3)$ and $SU(2)$ gauge fields

$$\mathcal{L}_{gT,0} = \frac{F_{gT,0}}{16} \sum_a \hat{G}^a_{\mu\nu} \hat{G}^{a,\mu\nu} \times \sum_i \hat{W}^i_{\alpha\beta} \hat{W}^{i,\alpha\beta} ,$$

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$SU(3)$ and $U(1)$ gauge fields

$$\mathcal{L}_{gT,4} = \frac{F_{gT,4}}{16} \sum_a \hat{G}^a_{\mu\nu} \hat{G}^{a,\mu\nu} \times B_{\alpha\beta} B^{\alpha\beta} ,$$

$$\mathcal{L}_{gT,5} = \frac{F_{gT,5}}{16} \sum_a \hat{G}^a_{\alpha\nu} \hat{G}^{a,\mu\beta} \times B_{\mu\beta} B^{\alpha\nu} ,$$

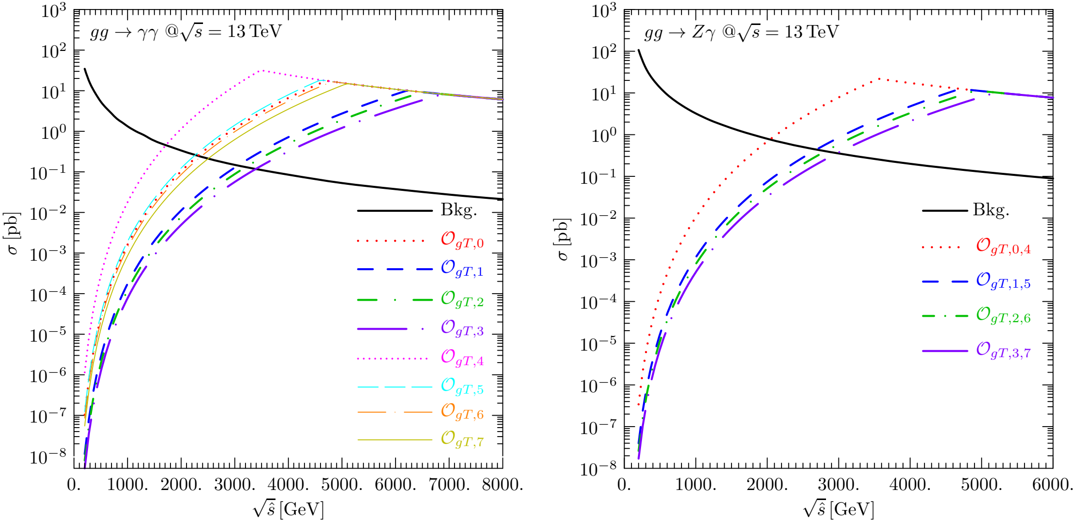
$$\mathcal{L}_{gT,6} = \frac{F_{gT,6}}{16} \sum_a \hat{G}^a_{\alpha\mu} \hat{G}^{a,\mu\beta} \times B_{\nu\beta} B^{\alpha\nu} ,$$

$$\mathcal{L}_{gT,7} = \frac{F_{gT,7}}{16} \sum_a \hat{G}^a_{\alpha\mu} \hat{G}^a_{\beta\nu} \times B^{\mu\beta} B^{\nu\alpha} .$$

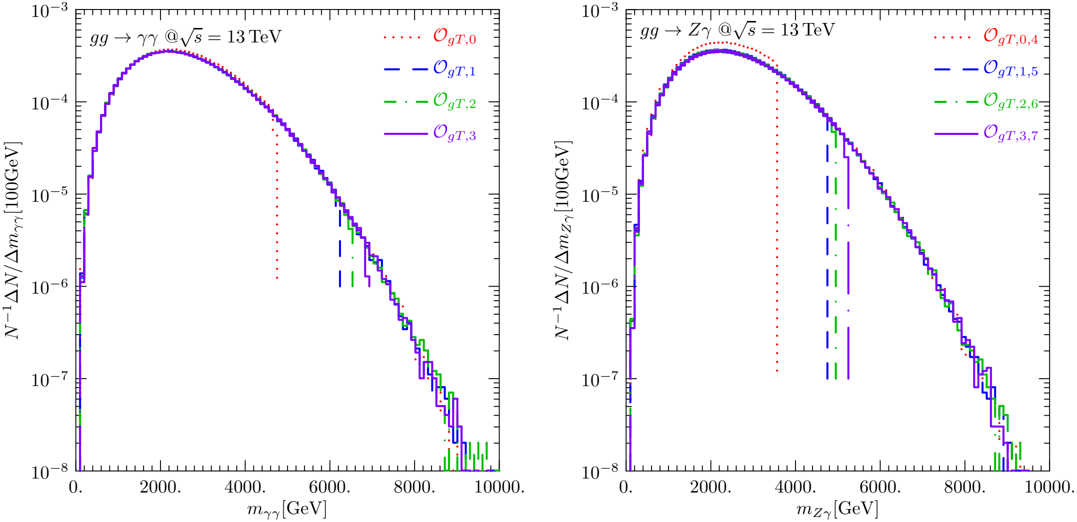
$$\sum_i W^i W^i = W^3 W^3 + \cdots = s_w^2 AA + 2 c_w s_w ZA + c_w^2 ZZ + \cdots ,$$

$$BB = c_w^2 AA - 2 c_w s_w ZA + s_w^2 ZZ + \cdots ,$$

Unitarity Problem



Unitarity Problem

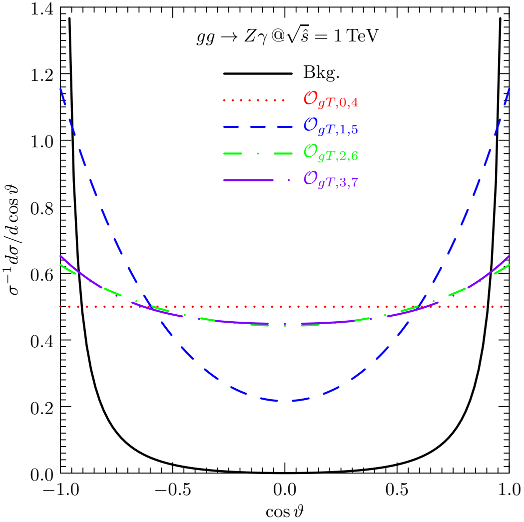


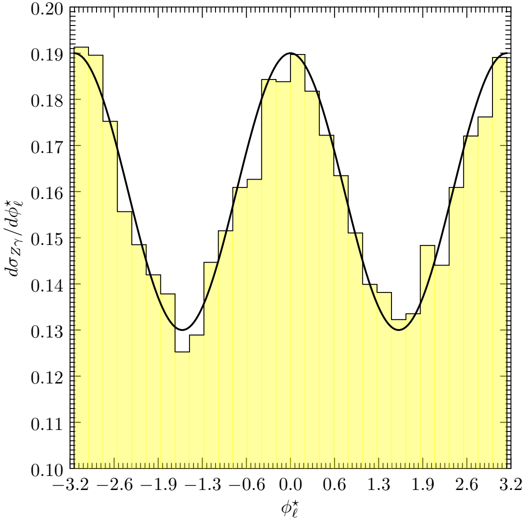
Kinematical Distribution

$$\frac{d\sigma_{gg\to Z\gamma}}{d\cos\vartheta} = \frac{x_Z(1-x_Z)^3\,\hat{s}^4}{\beta_i^8 m_Z^2}\begin{cases} \frac{1}{2^{14}\pi} & i=0,4 \\ \frac{1}{2^{23}\pi}\Big[73+52\cos(2\vartheta)+3\cos(4\vartheta)+40x_Z\sin^2\vartheta \\ \qquad +24x_Z\sin^2\vartheta\cos(2\vartheta)+24x_Z^2\sin^4(\vartheta)\Big] & i=1,5 \\ \frac{1}{2^{25}\pi}\Big[163+28\cos(2\vartheta)+\cos(4\vartheta) \\ \qquad +8x_Z\sin^2\vartheta\big(3+\cos(2\vartheta)\big)+8x_Z^2\sin^4\vartheta\Big] & i=2,6 \\ \frac{1}{2^{25}\pi}\Big[105+20\cos(2\vartheta)+3\cos(4\vartheta) \\ \qquad +8x_Z\sin^2\vartheta\big(5+3\cos(2\vartheta)\big)+24x_Z^2\sin^4\vartheta\Big] & i=3,7\,, \end{cases}$$

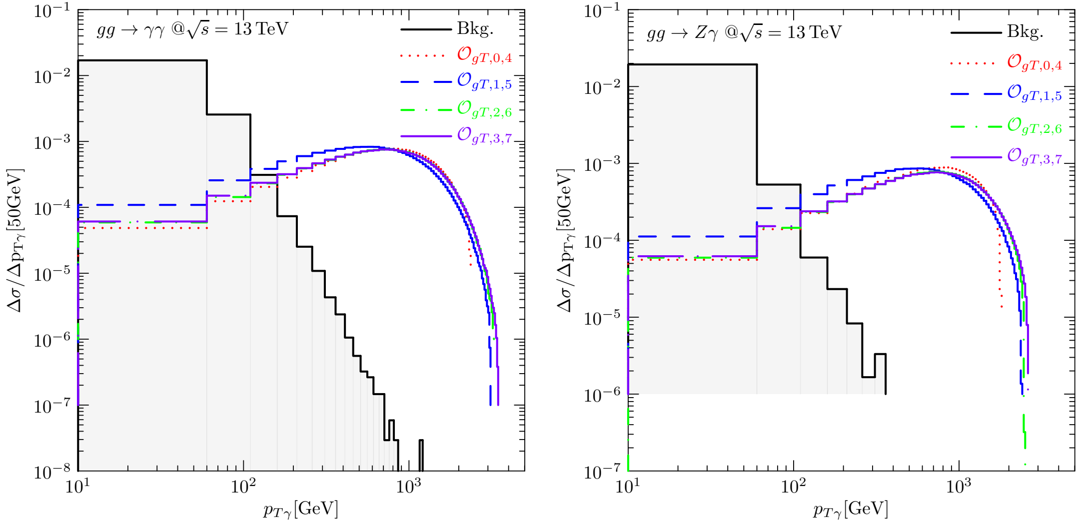
where $x_Z \equiv m_Z^2/\hat{s}$ and ϑ is the polar scattering angle.

Kinematical Distribution

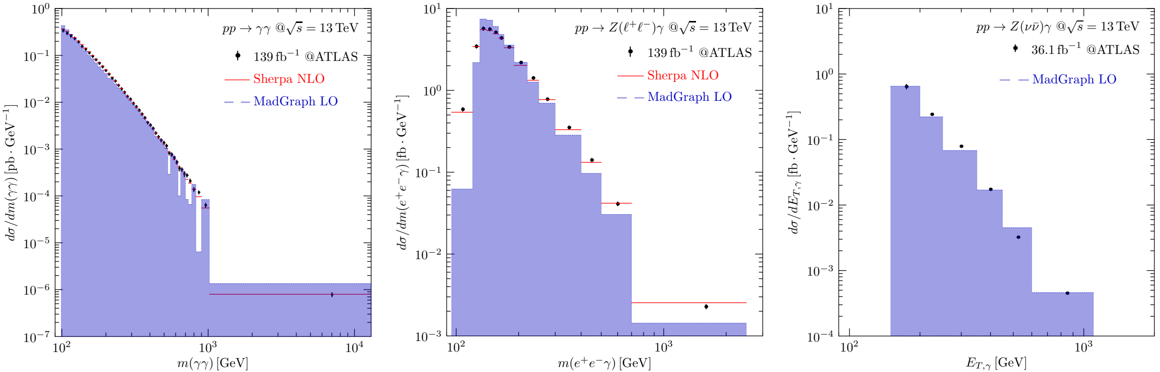




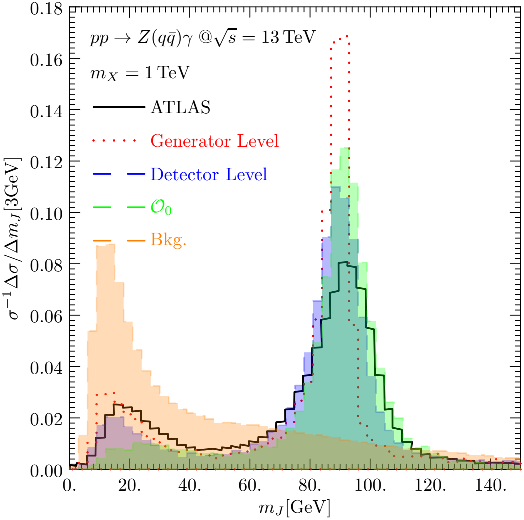
Kinematical Distribution

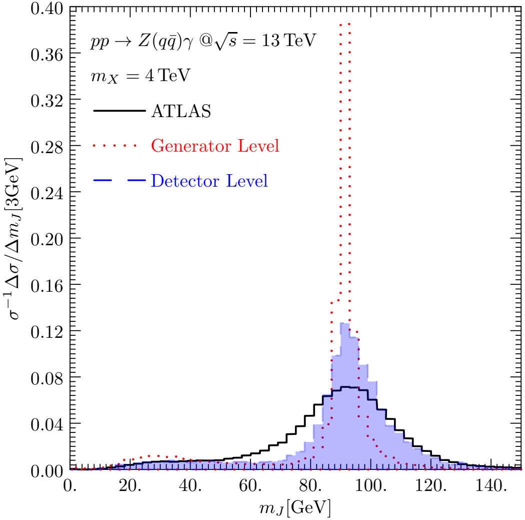


Experimental Constraints @13TeV



Experimental Constraints @13TeV





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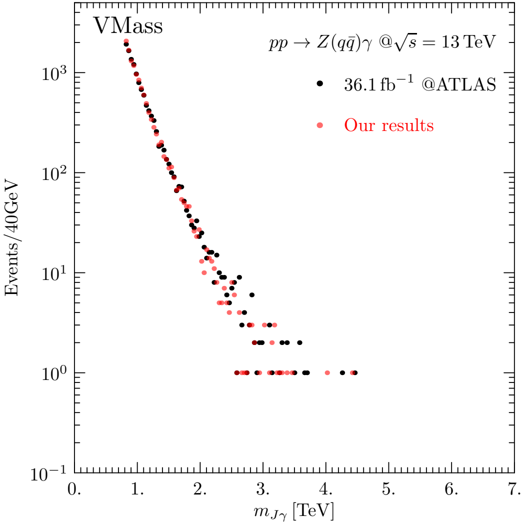
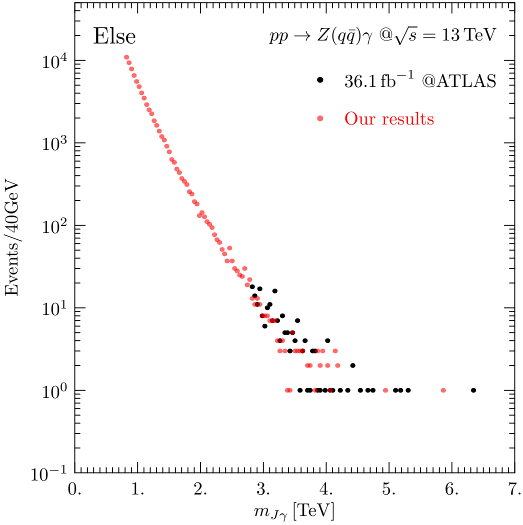
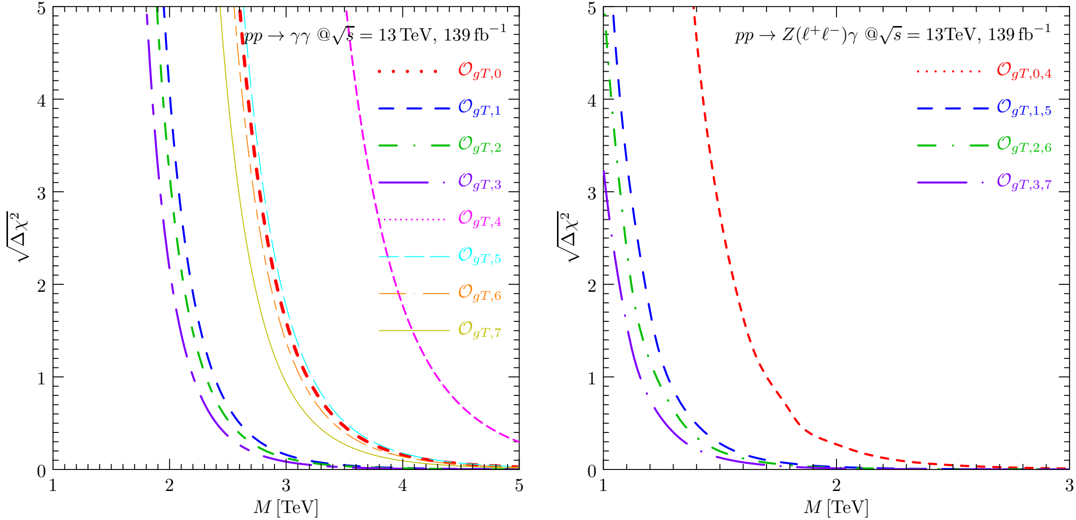
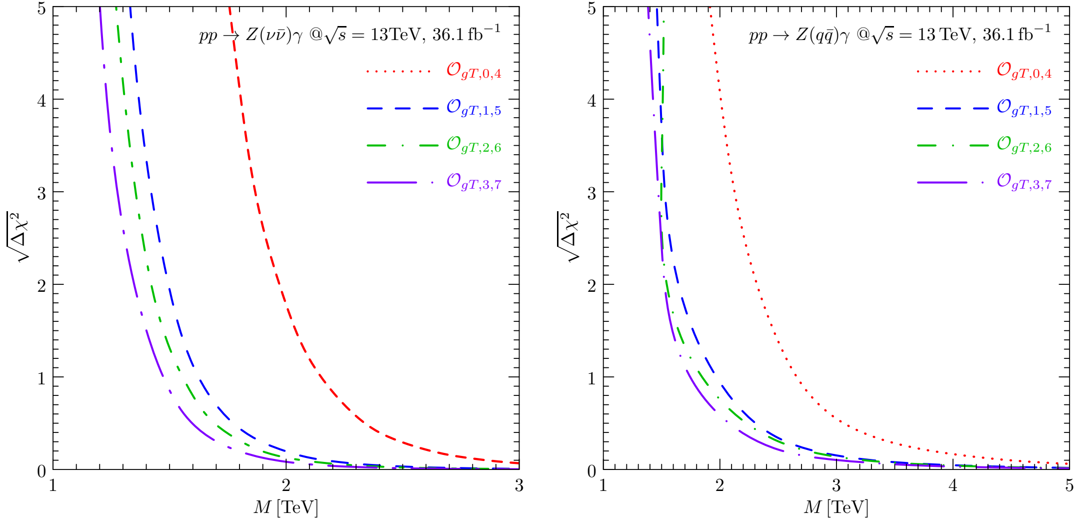




Experimental Constraints @13TeV



Experimental Constraints @13TeV



Experimental Constraints @Born-Infield Model

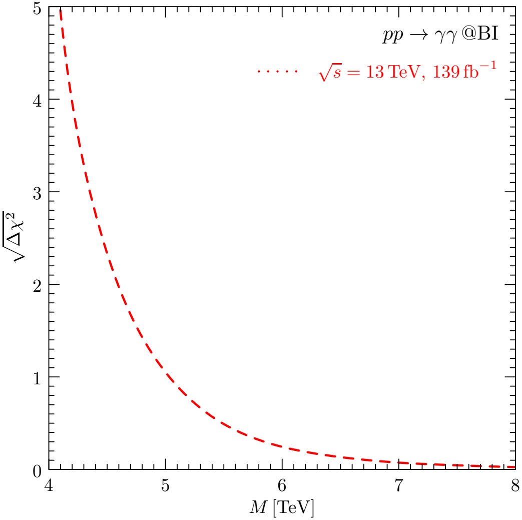
$$\mathcal{L}_{\rm BI} = \beta^2 \left[1 - \sqrt{1 + \frac{F^{\lambda}_{\mu\nu} F^{\lambda,\mu\nu}}{2\beta^2} - \left(\frac{F^{\lambda}_{\mu\nu} \widetilde{F}^{\lambda,\mu\nu}}{4\beta^2} \right)^2} \right]$$

$$\mathcal{L}_{\rm BI} \ni \frac{1}{16M^4} \left[{\rm Tr}(GG){\rm Tr}(WW) + {\rm Tr}(G\tilde{G}){\rm Tr}(W\tilde{W}) \right]$$

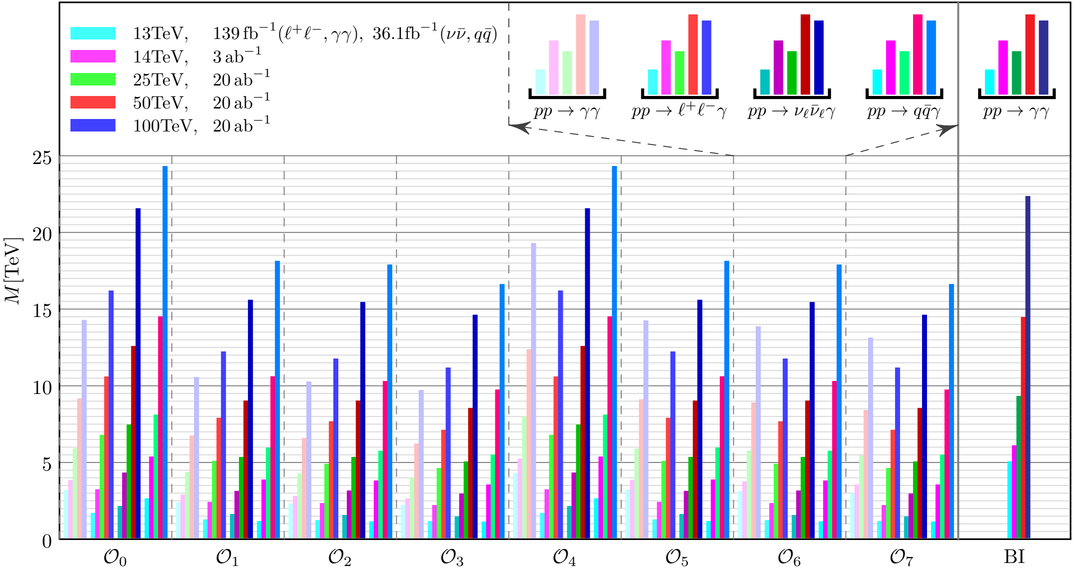
$$+ \quad \{W \to B\},$$

$$\mathcal{L}_{\rm BISM} \ni \mathcal{L}_{gT,0} - 2\mathcal{L}_{gT,1} + 4\mathcal{L}_{gT,3}$$

$$+ \quad \mathcal{L}_{gT,4} - 2\mathcal{L}_{gT,5} + 4\mathcal{L}_{gT,7}$$

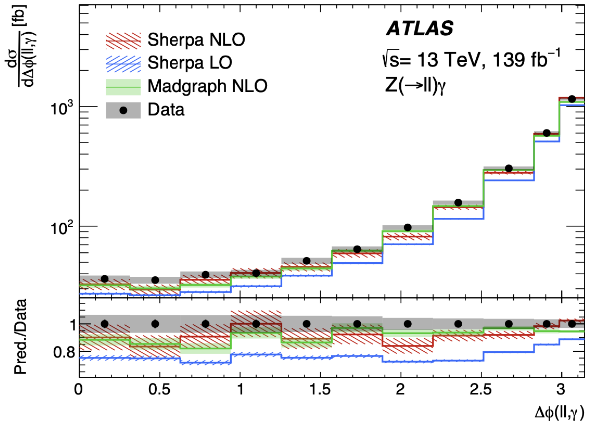


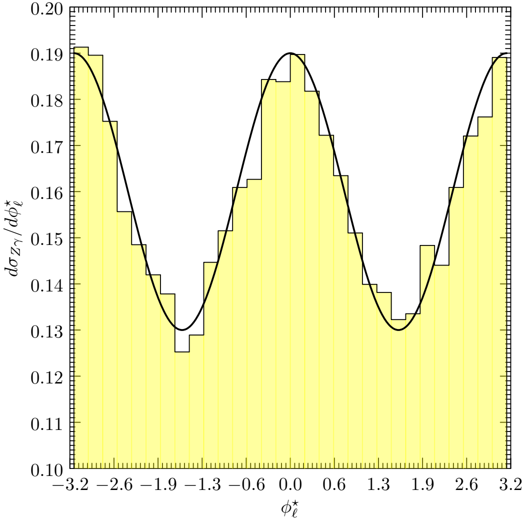
Experimental Constraints @Future Colliders



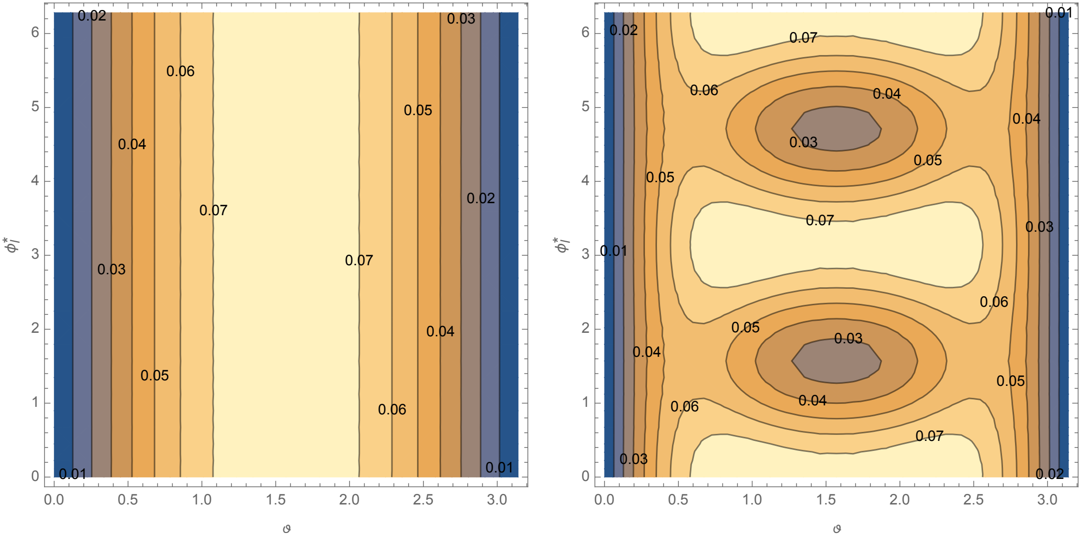
Spin Correlations

Spin Correlation @Azimuthal Correlation

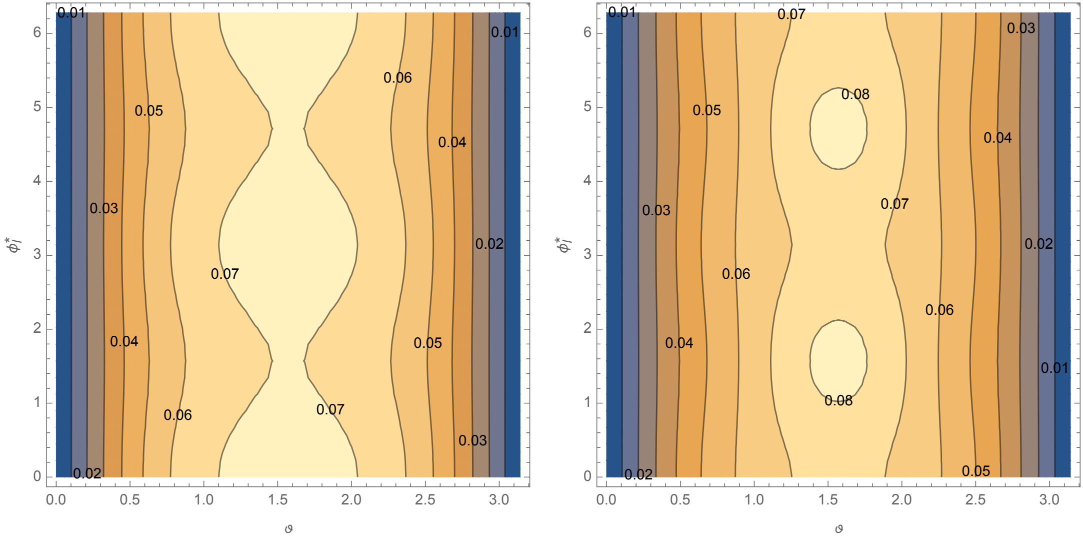




Spin Correlation @Polar-Azimuthal Correlation



Spin Correlation @Polar-Azimuthal Correlation




Thank you.