LIGHT BY LIGHT SCATTERING AND THE 750 GEV DIPHOTON EXCESS

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CERN, 15/03/2016

Based on work with Sylvain Fichet & Christophe Royon
1512.05751 and 1601.01712

PUC RIO Departamento de Física

ICTP SAIFR International Centre for Theoretical Physics
South American Institute for Fundamental Research

INTRODUCTION

The excess at 750 GeV - ATLAS

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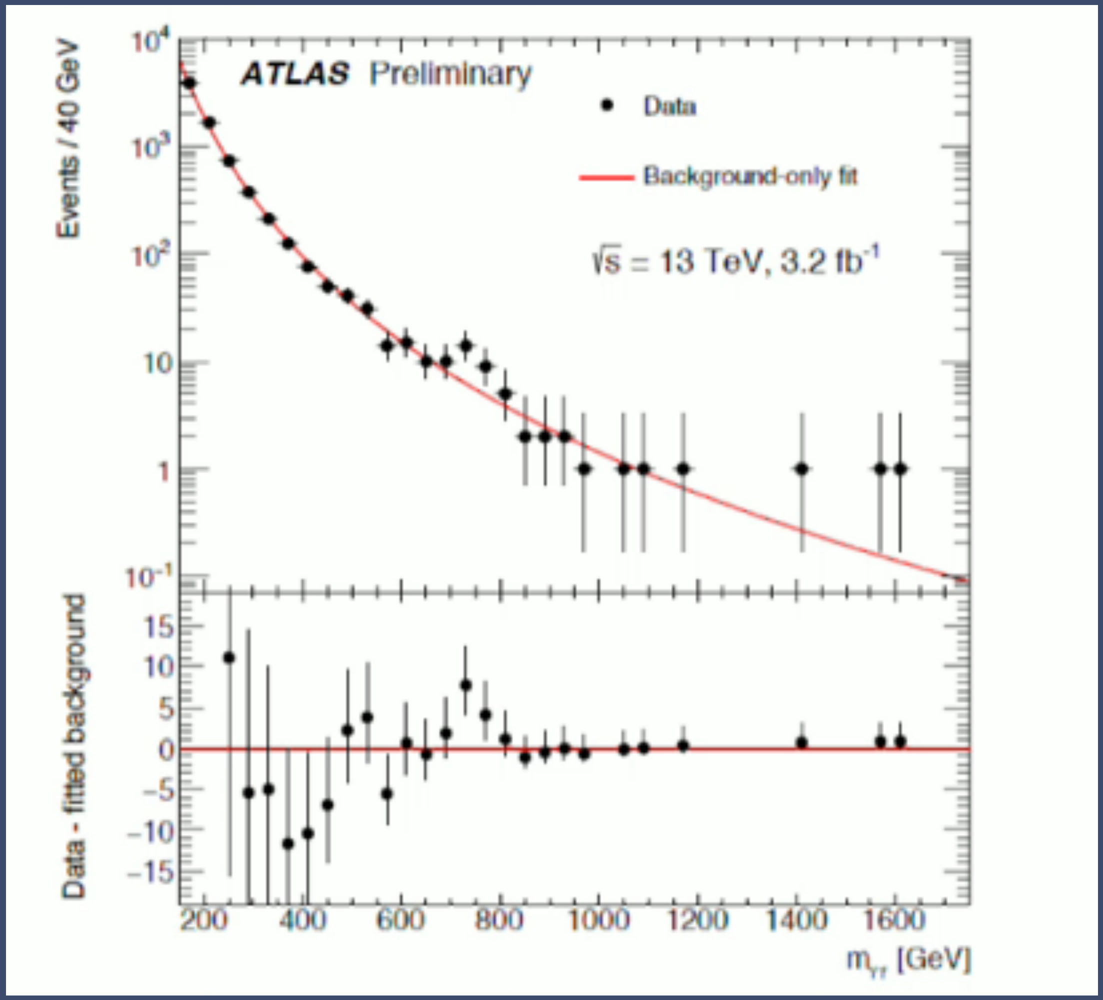

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- Local: 3.9 σ
- Global: 2.3 σ

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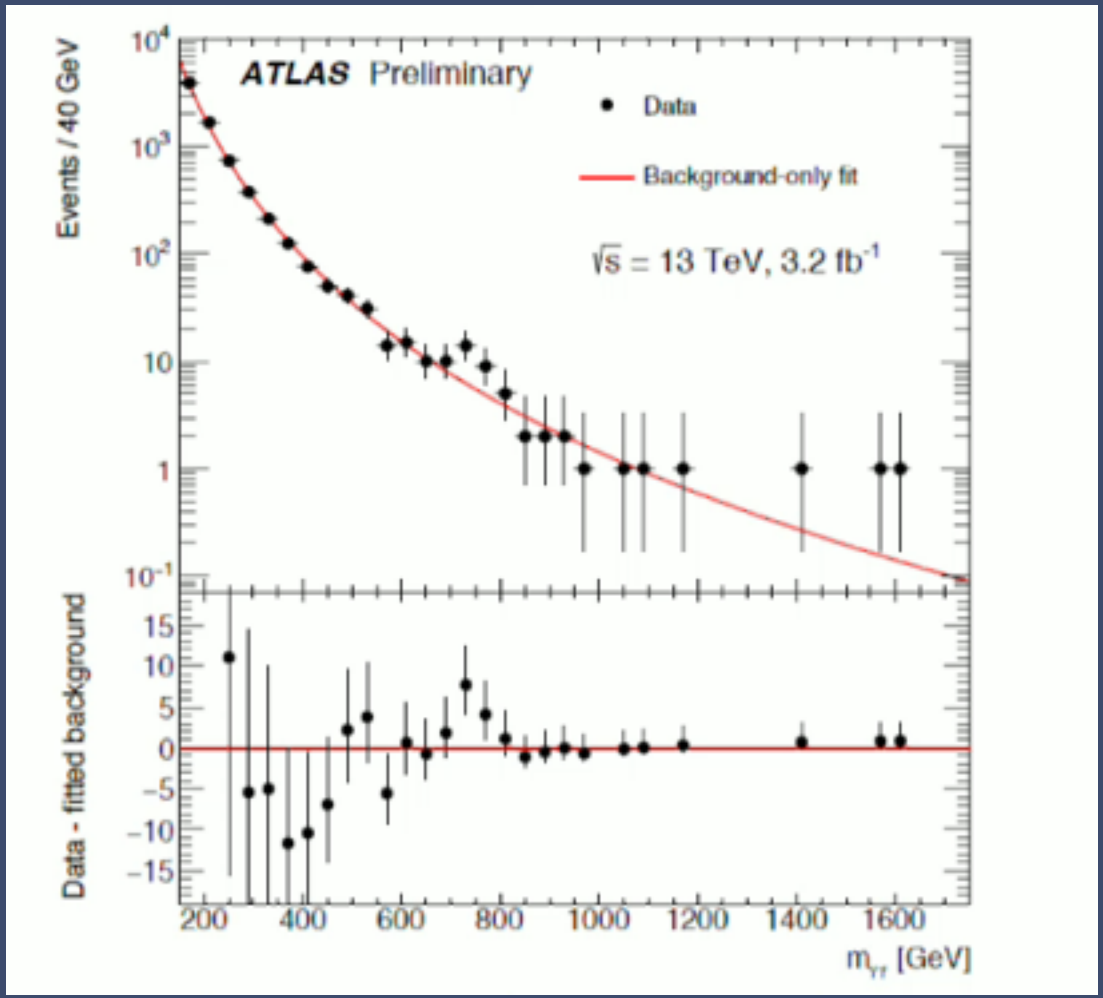
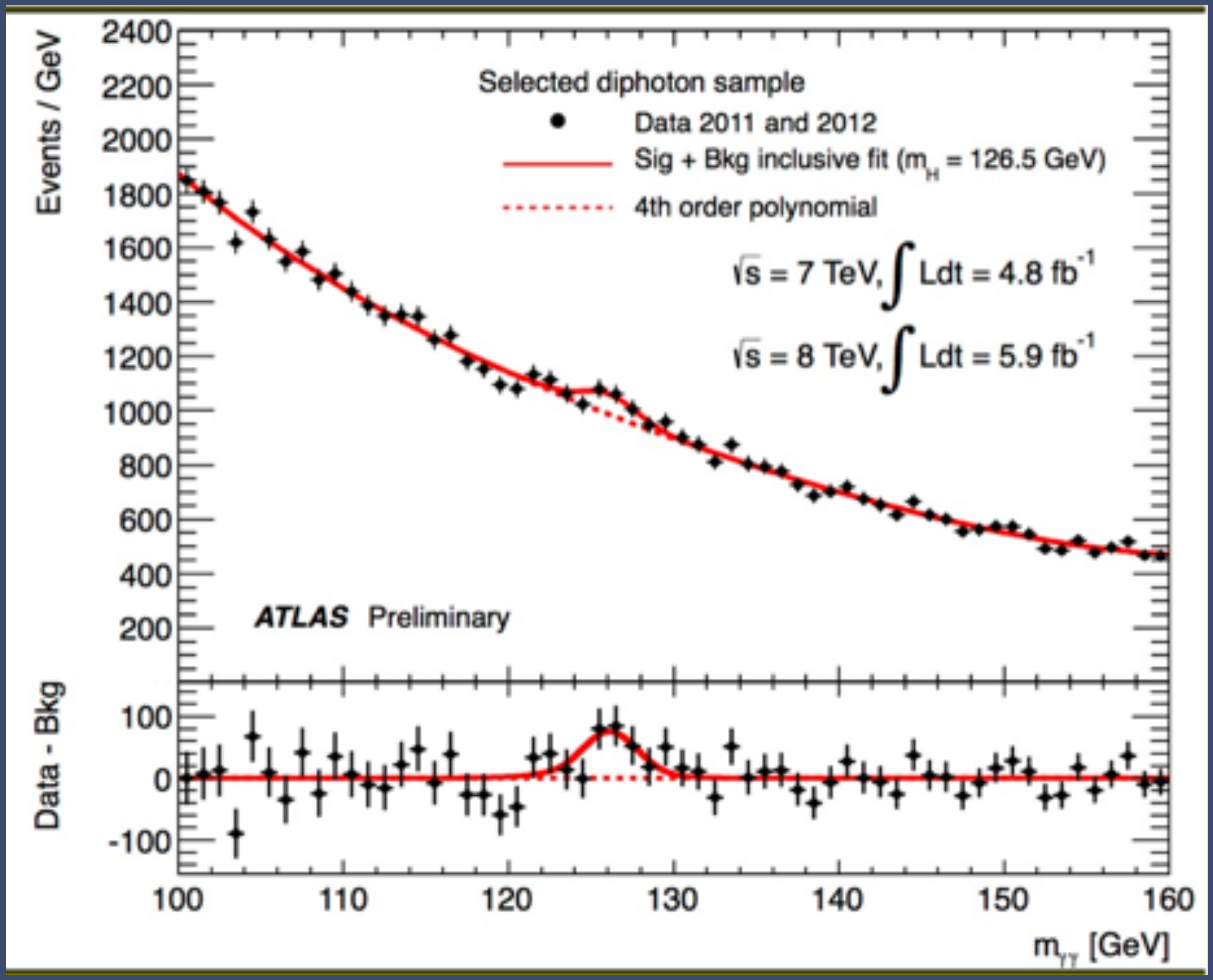


Compare with the Higgs
(roughly 3x the statistics…)



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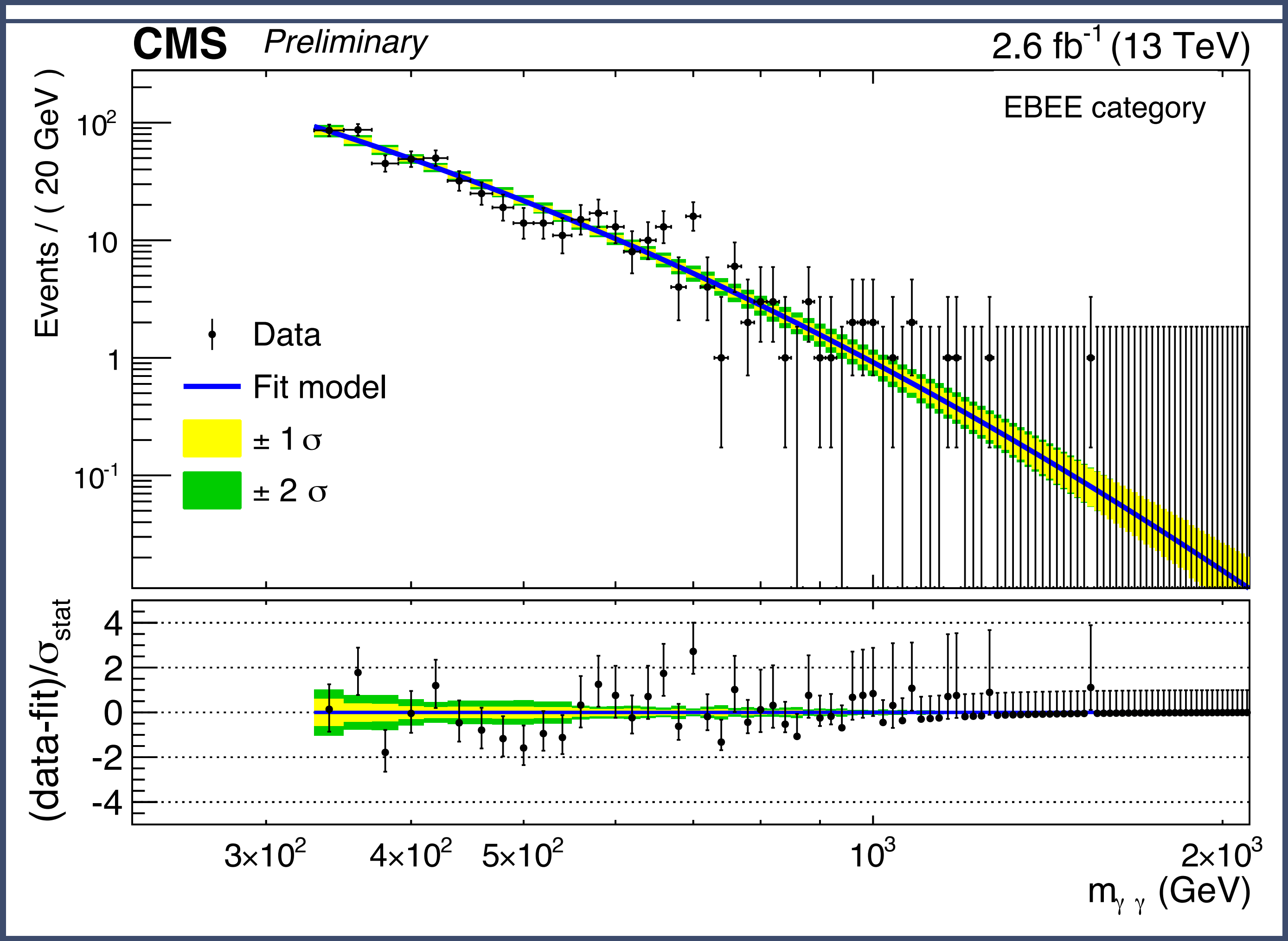
THE EXCESS AT 750 GEV - CMS



CMS: 20 fb^{-1} (8 TeV) + 2.6 fb^{-1} (13 TeV)

- Local: 3.0 σ
- Global: 1.7 σ

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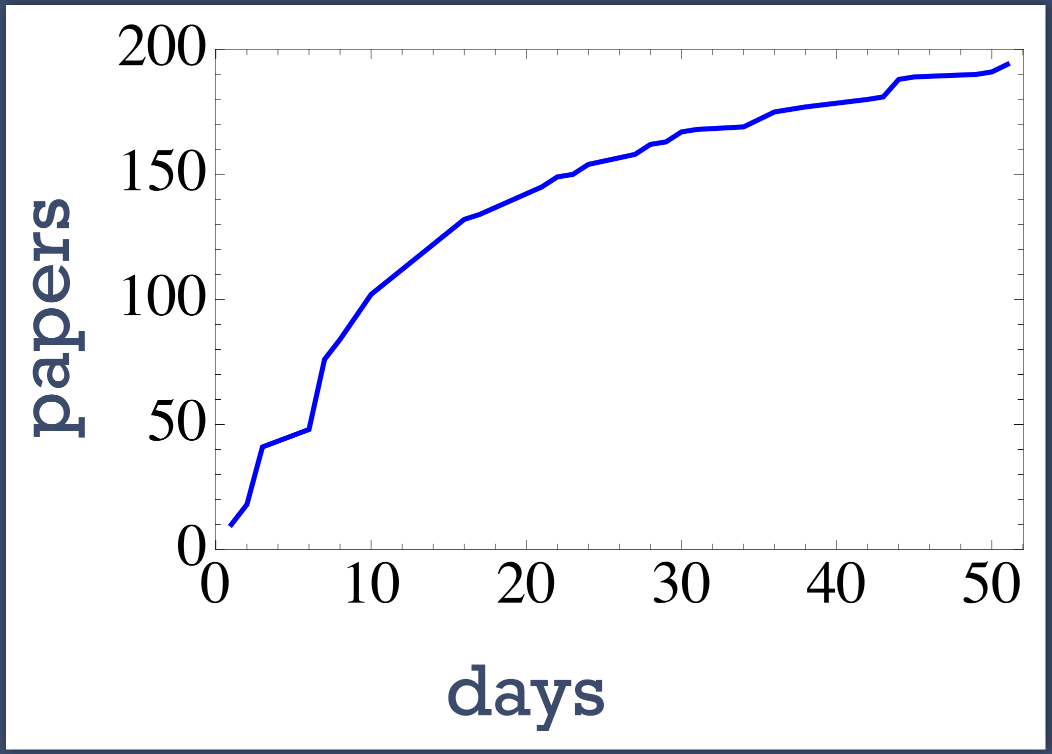

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- No electric charge $Q=0$

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- Landau-Yang theorem: spin-1 cannot decay into $\gamma\gamma$
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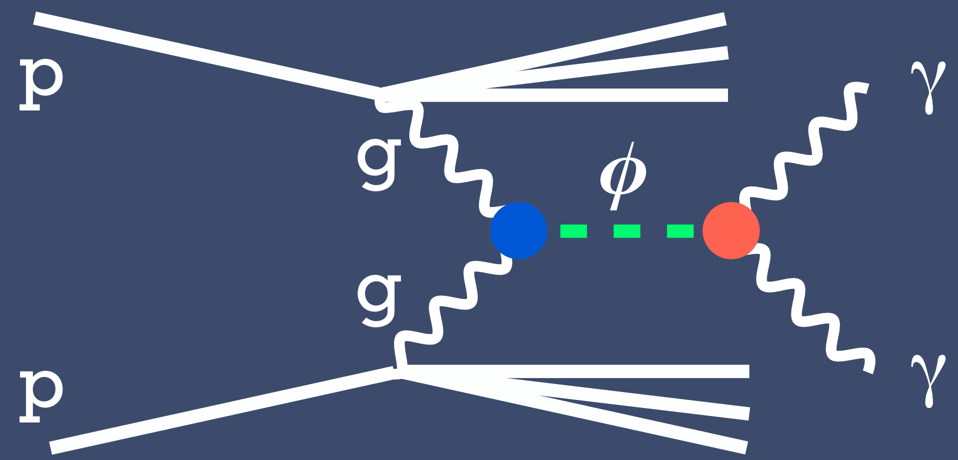

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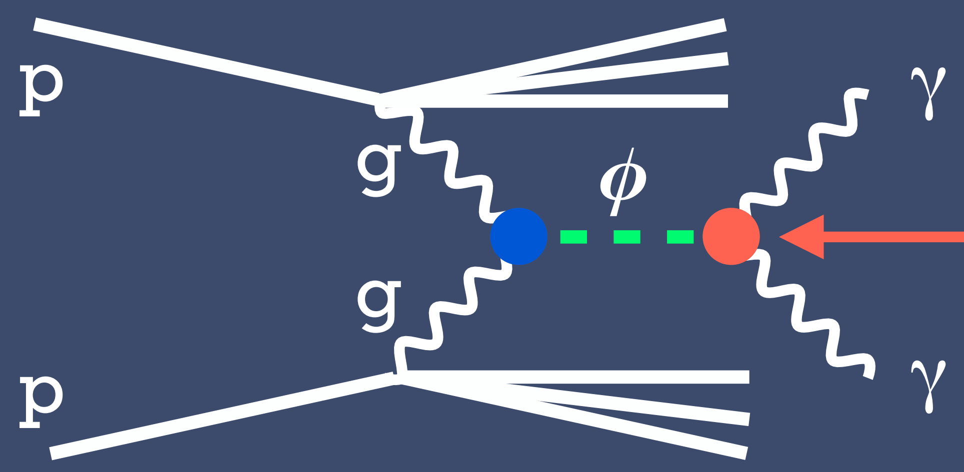

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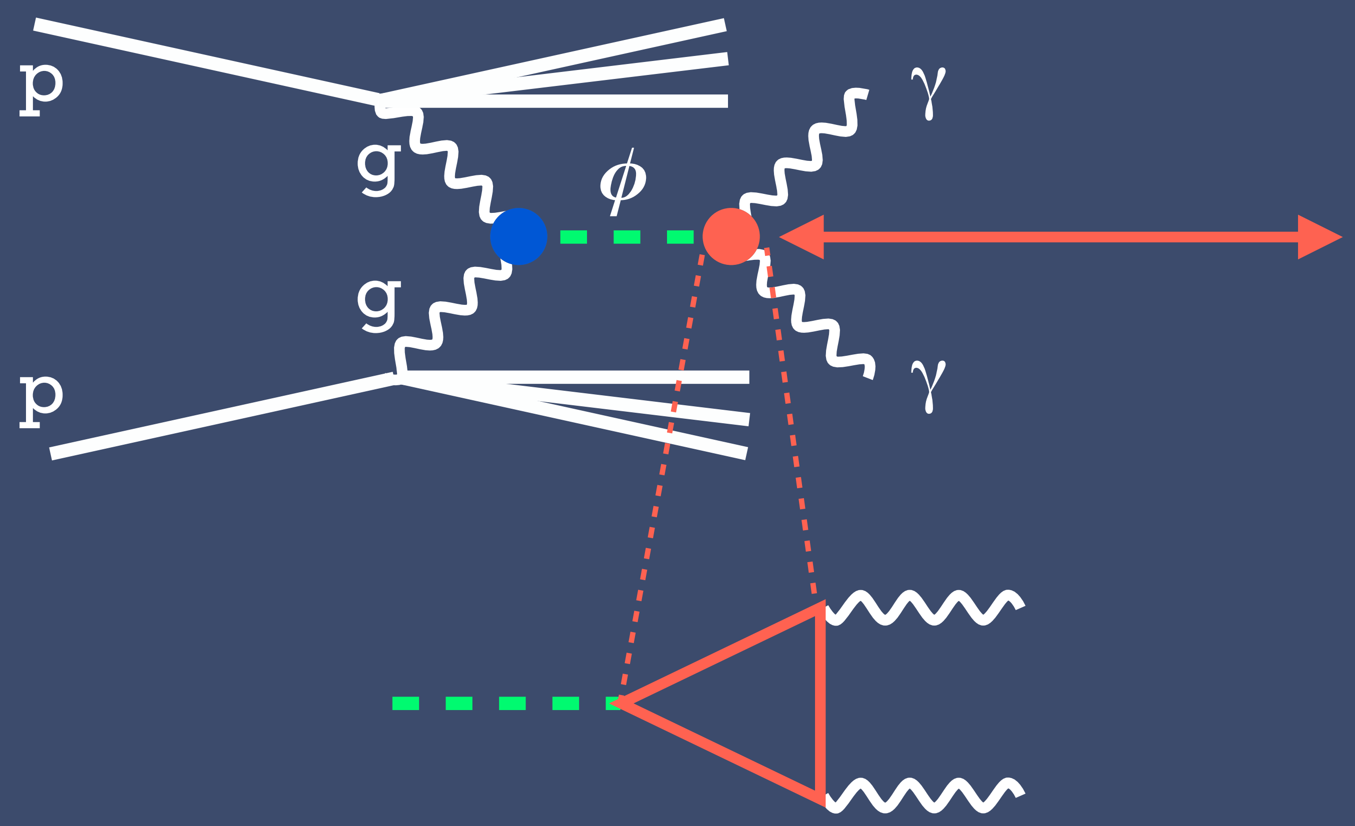

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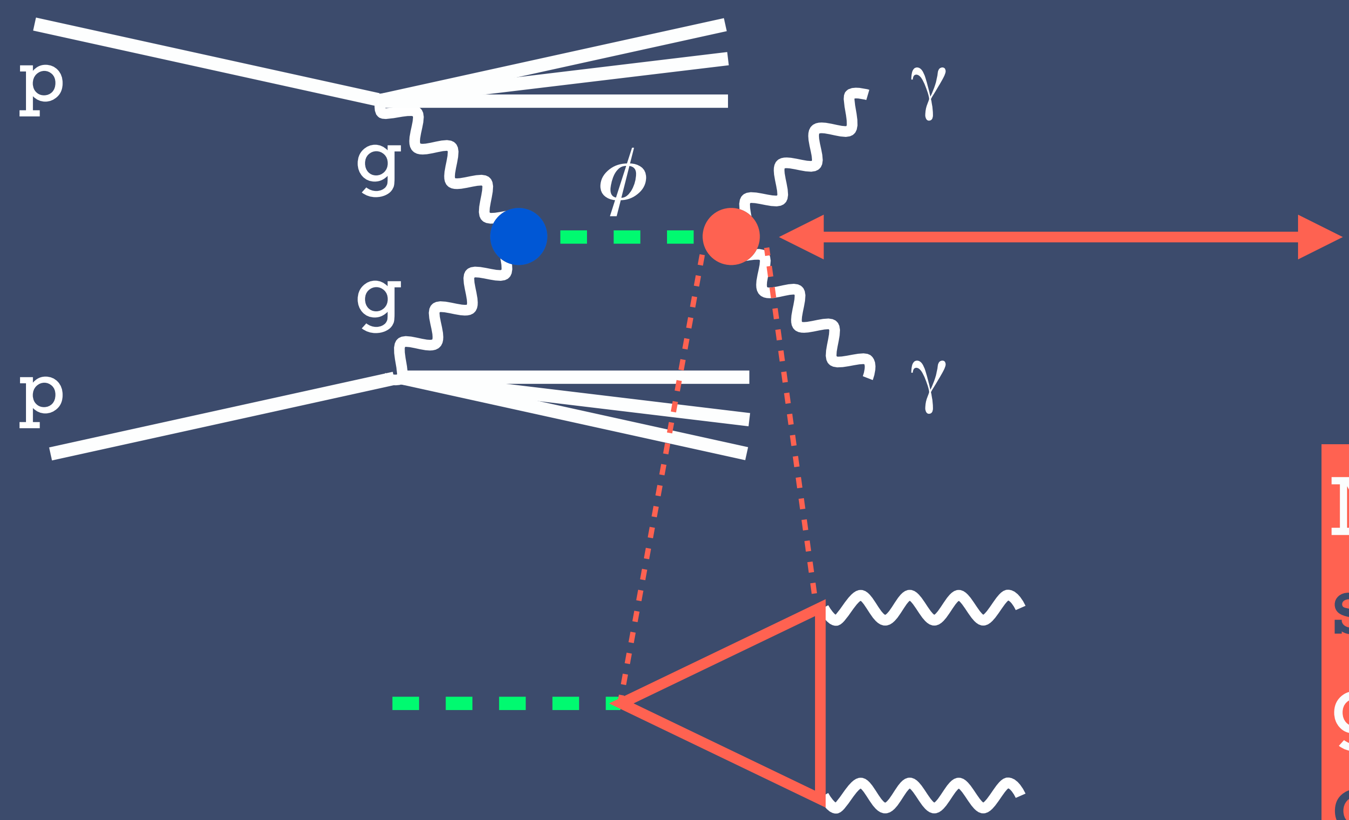

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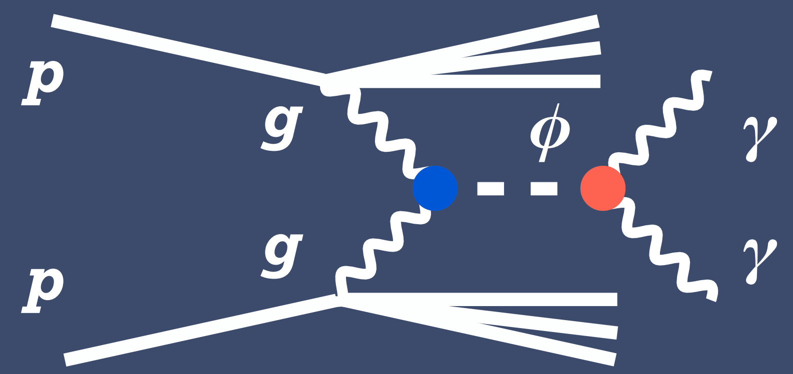
New States (fermions or scalars) are a fairly generic prediction if the diphoton excess is real

PART I:
PHOTON FUSION PRODUCTION

The production Mechanism

Gluon Fusion



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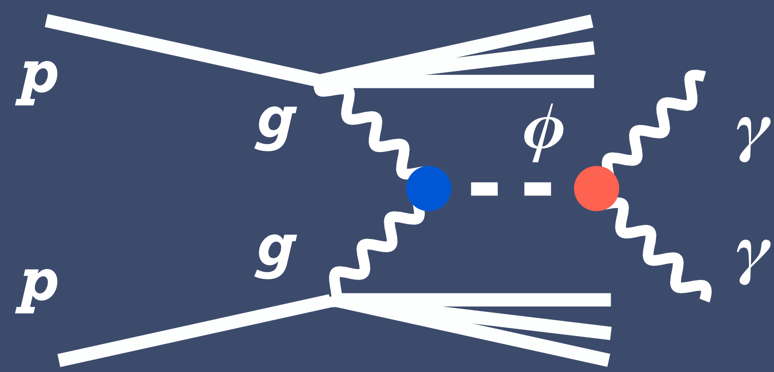

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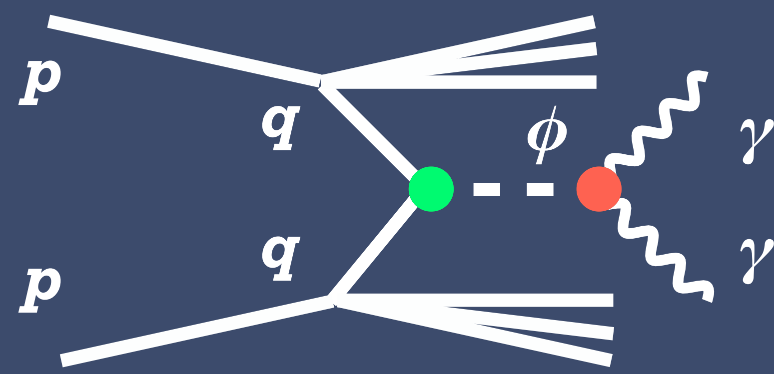

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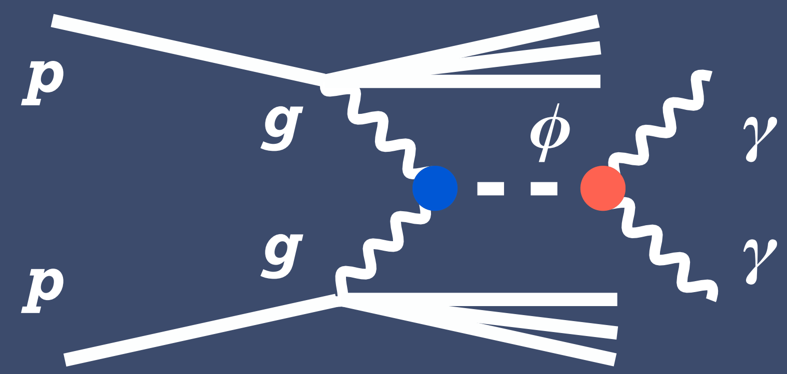

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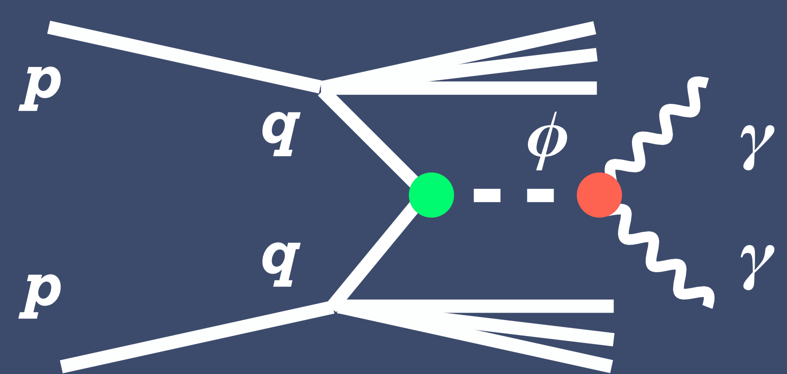

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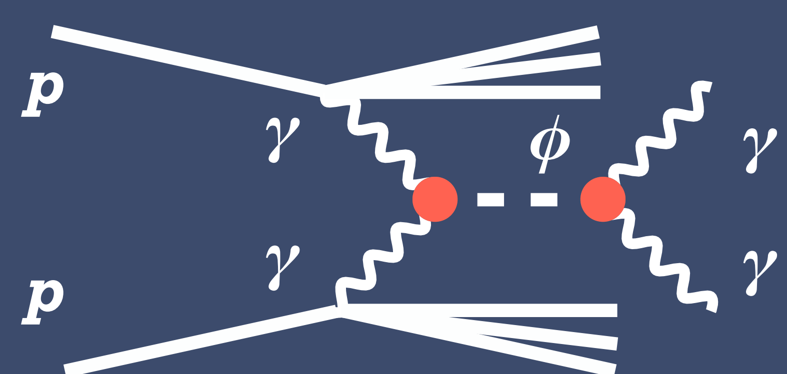

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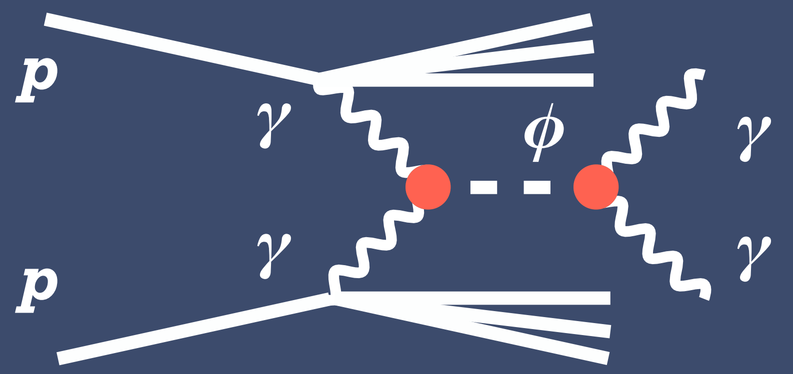
   - Model independent!
   - Infer f_γ from data!



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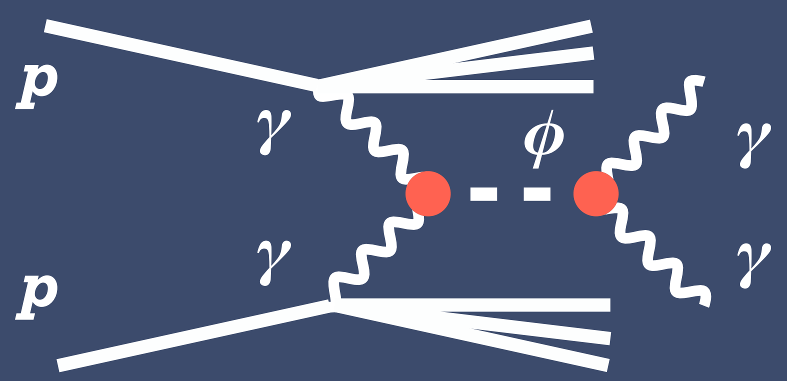
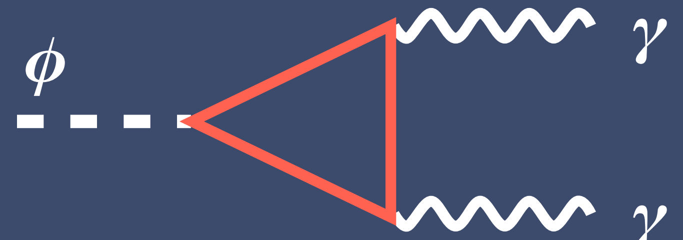


2. What is the effective coupling in terms of fundamental parameters?
   - Model-dependent!
   - Perturbativity?



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Fichet, GG, Royon 1512.05751

see also:
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- Determination of f_γ fairly accurate due to $f_\gamma \sim \sigma^{-1/4}$

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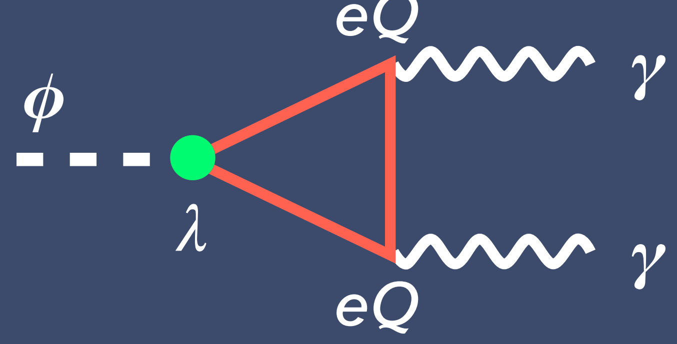

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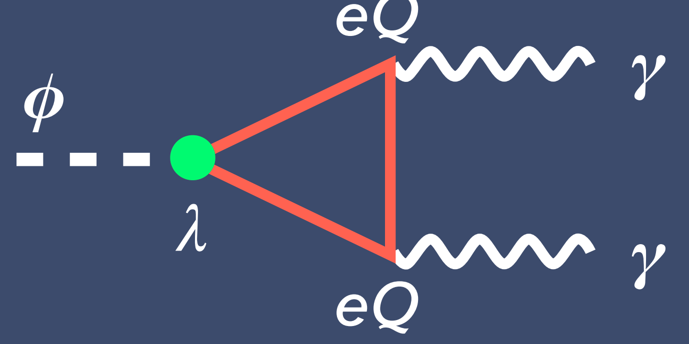

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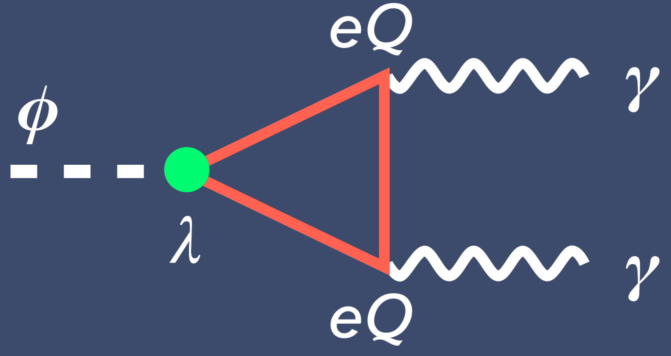

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- Width and cross section fix two combinations of Q, N, m_ψ, λ
- For instance: $Q = 5/2$, $N = 3$, $m_\psi = 360$ GeV, $\lambda = 5$
- Still perturbative: $\lambda N^{1/2} \sim 8.6 < 4\pi$

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Gross et al 1602.03877
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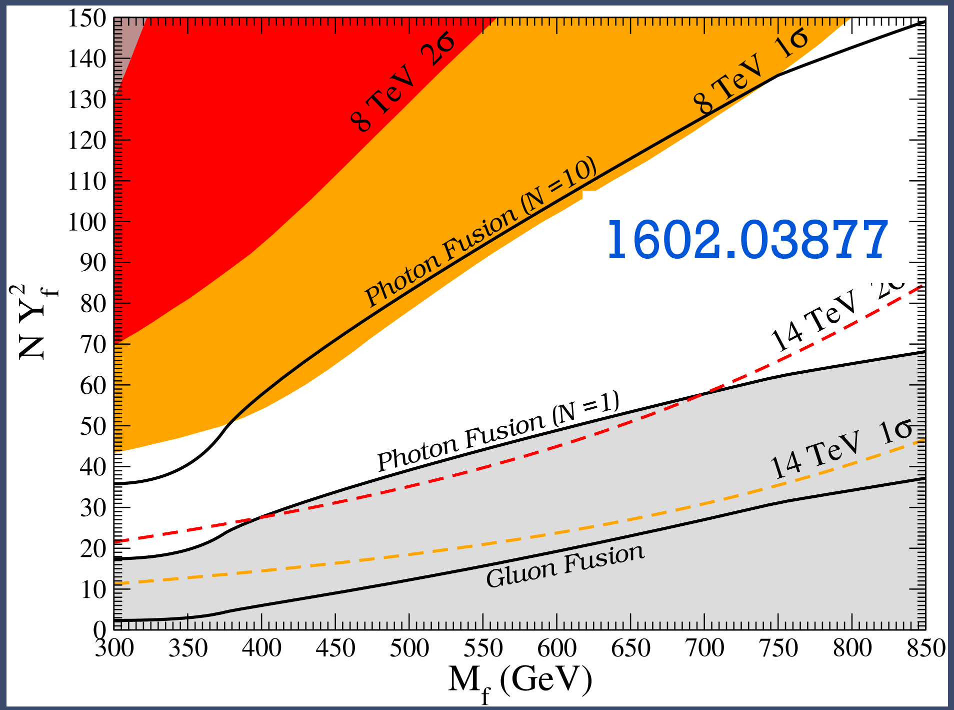

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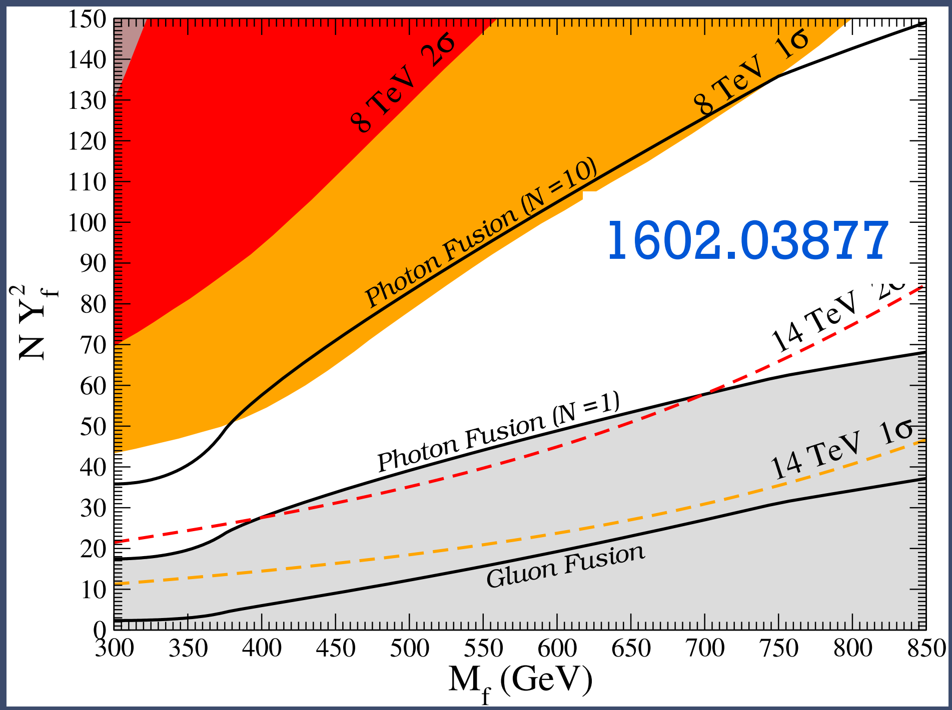

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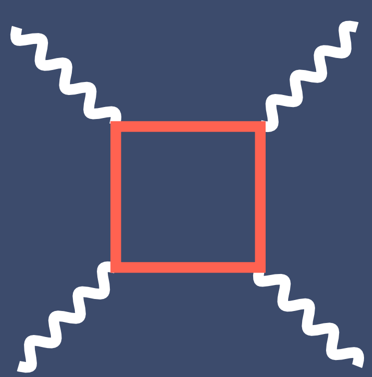

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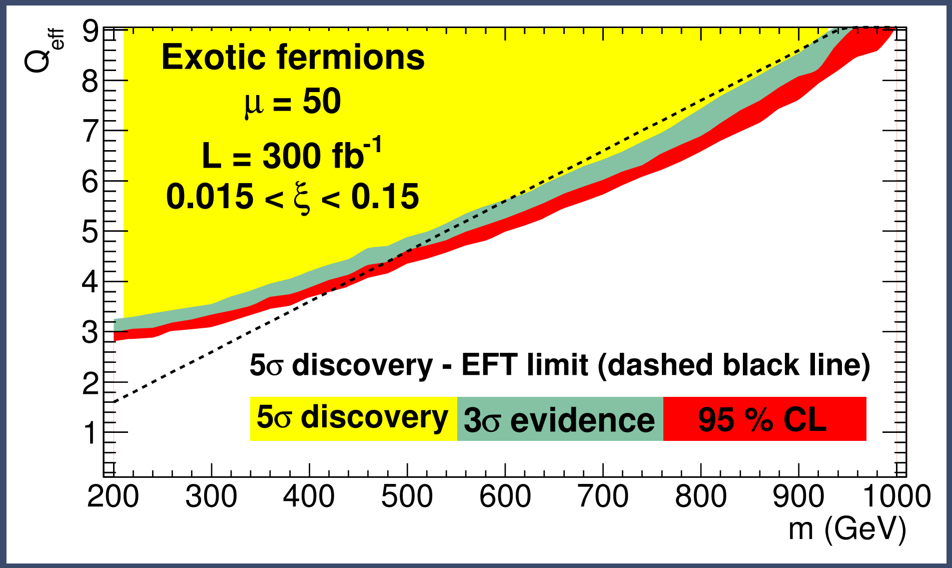

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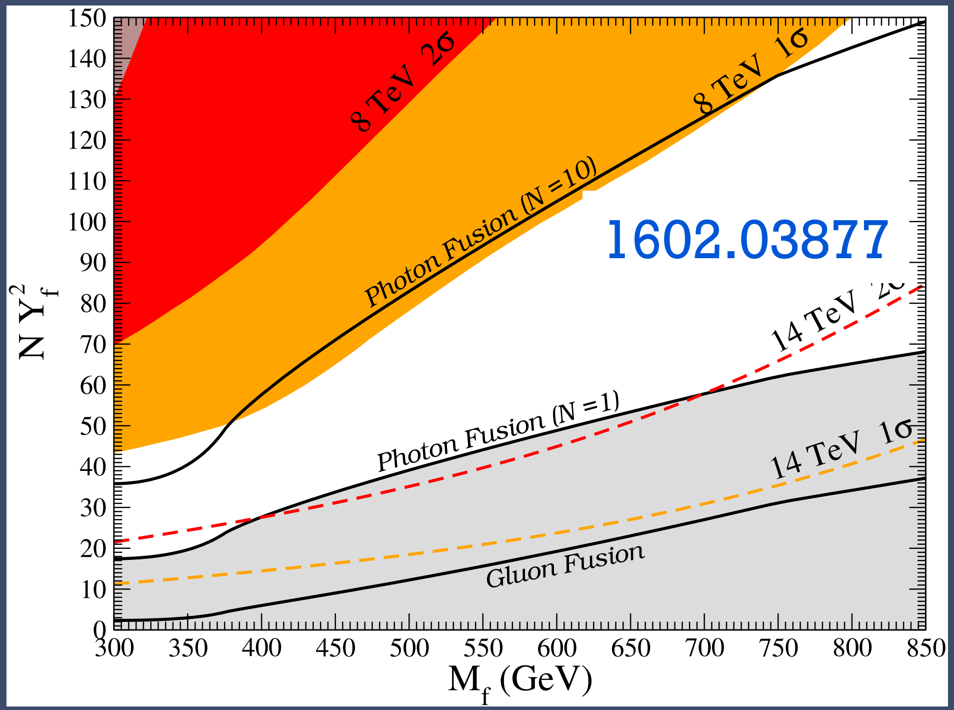

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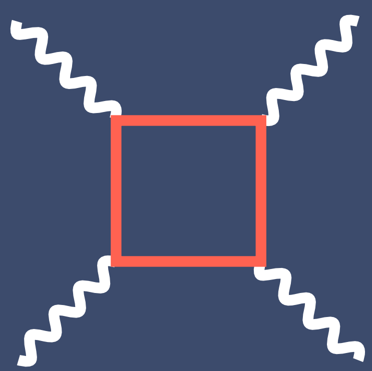

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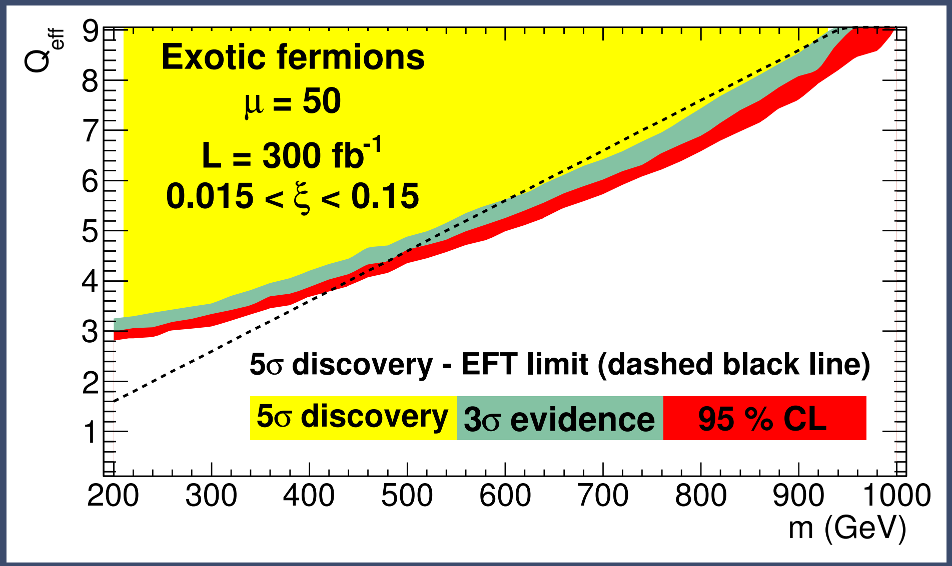

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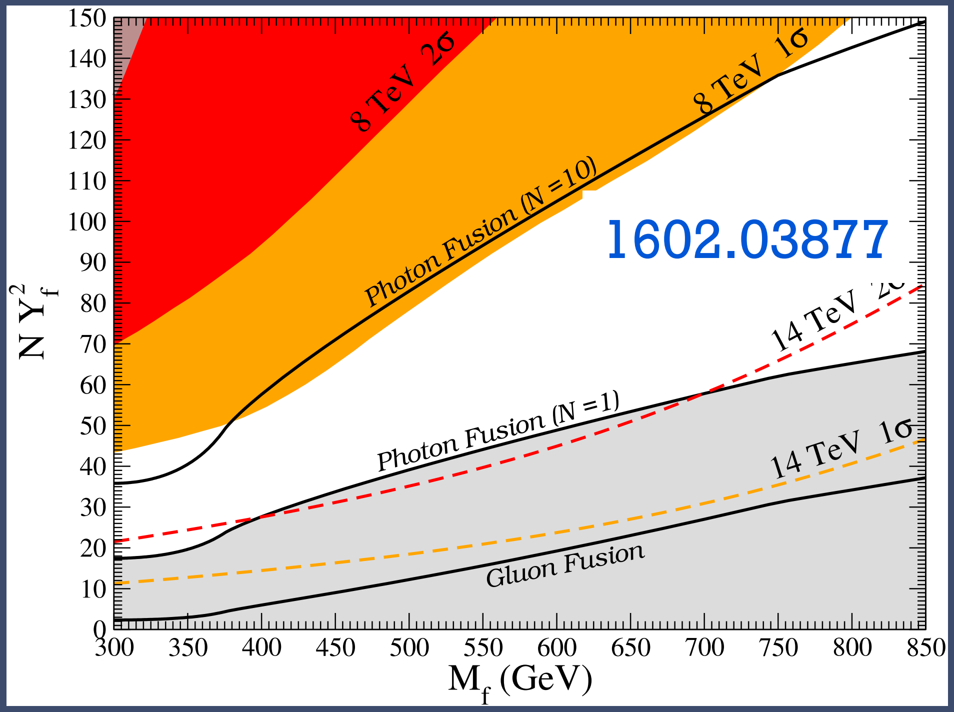

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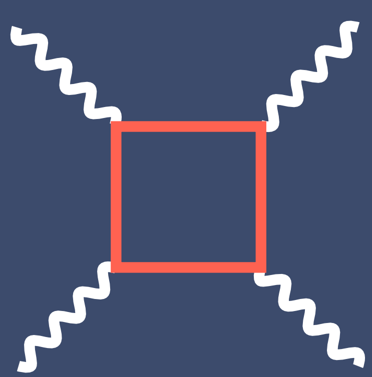

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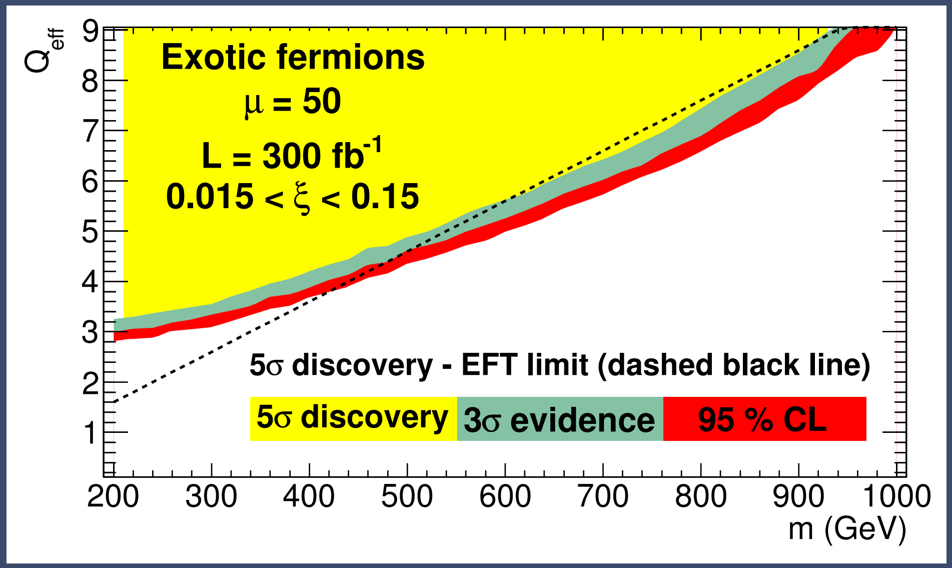

- Direct production of ψ at LHC…
- Landau Poles + Vacuum stability

Salvio et al 1602.03877

PART II:
MEASURING THE $\phi\gamma\gamma$ COUPLING

Aim

Aim

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- Assumed that only $\phi\gamma\gamma$ coupling is present (ϕgg and ϕqq vanishing or sufficiently suppressed)
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Now (part II):

- No assumptions on couplings or production mode (100% model independent)
- Is there a way to measure the $\phi\gamma\gamma$ coupling?

Inelastic vs elastic Production

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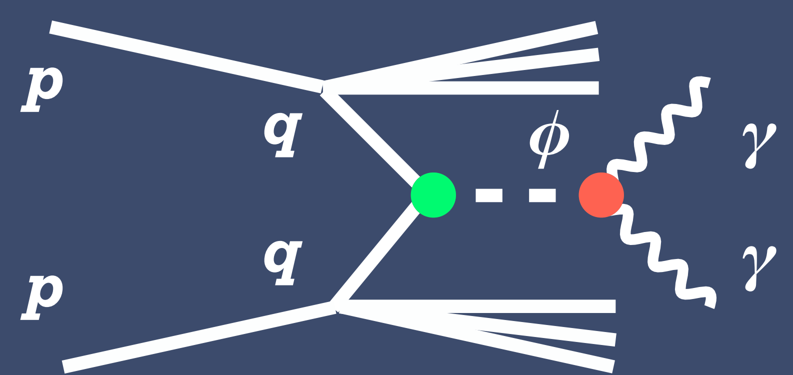
- Inelastic production (proton destroyed, dominant)



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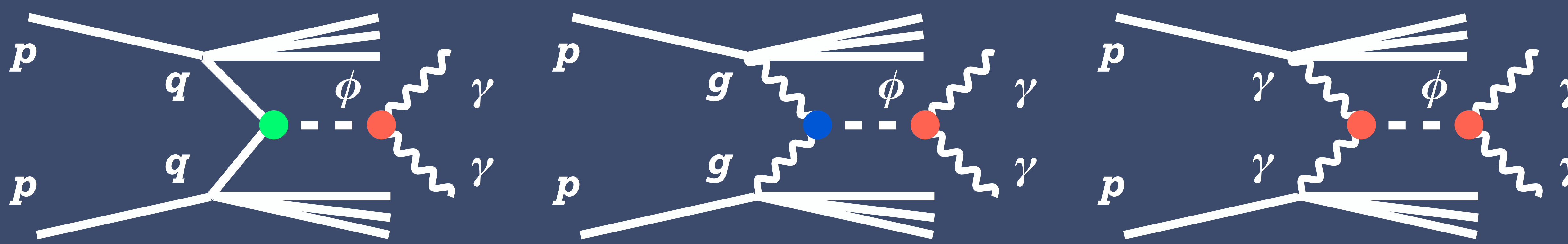

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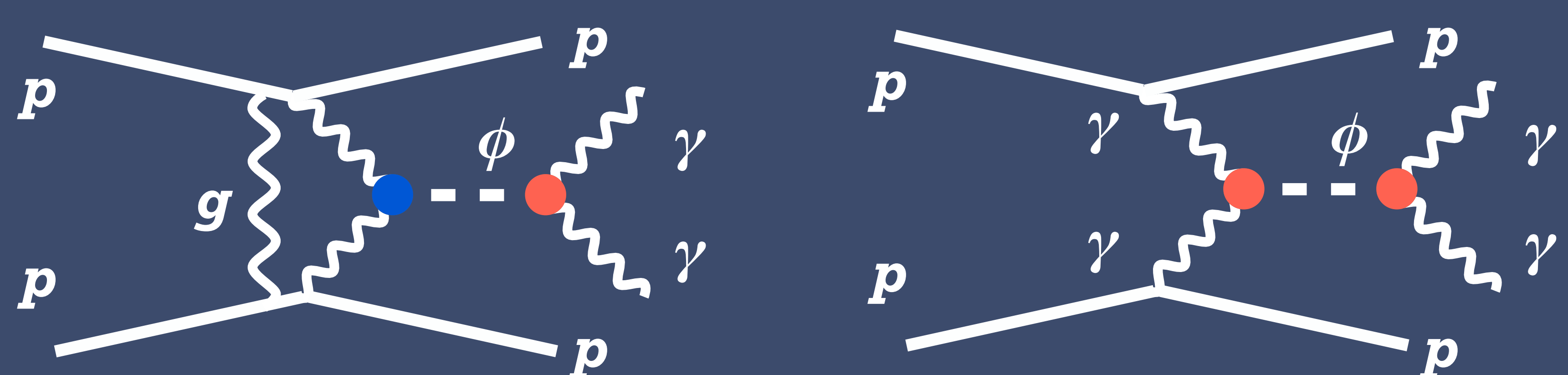

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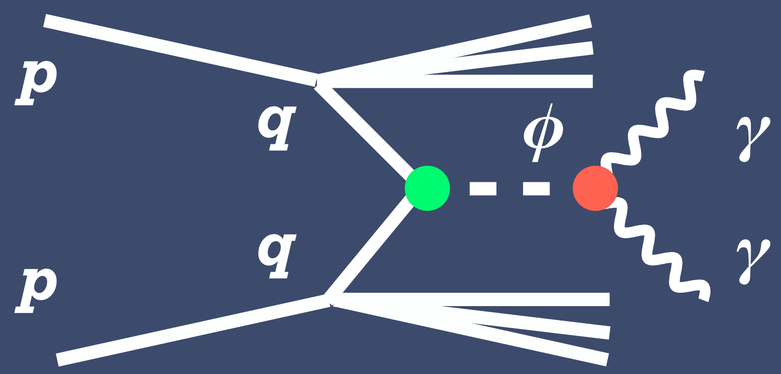

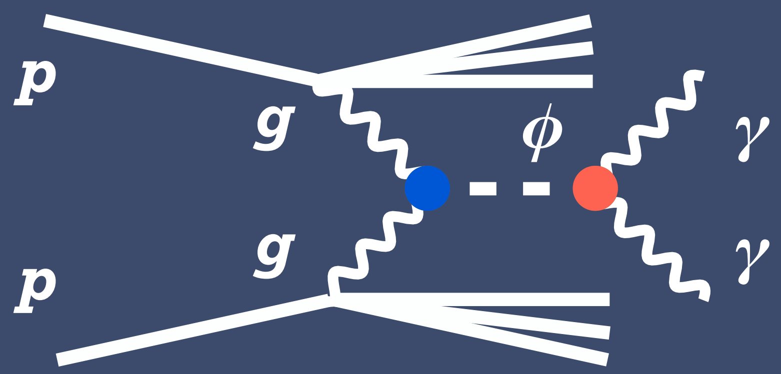

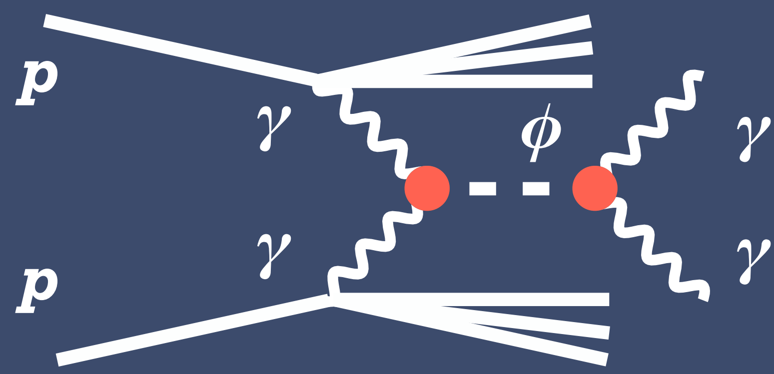

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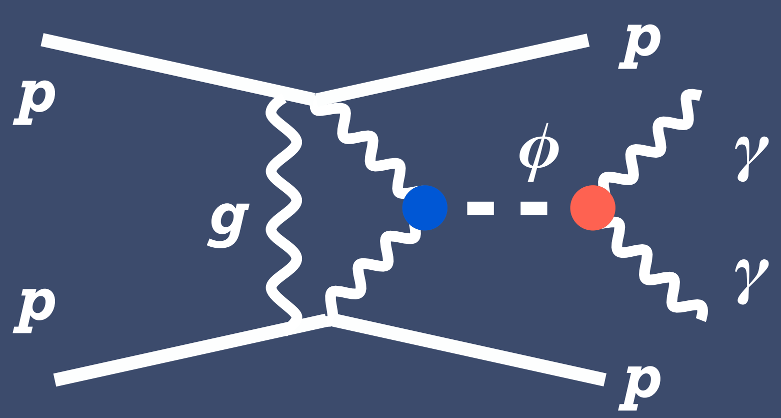

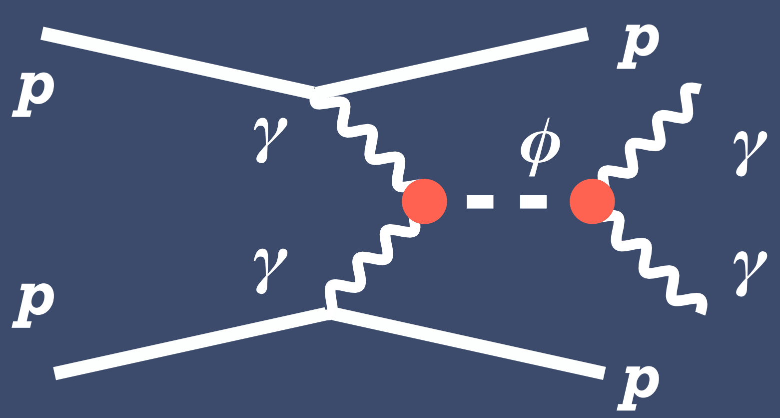

Suppression: $\sim 10^{-5}$ $\sim 10^{-1}$

INELASTIC VS ELASTIC PRODUCTION

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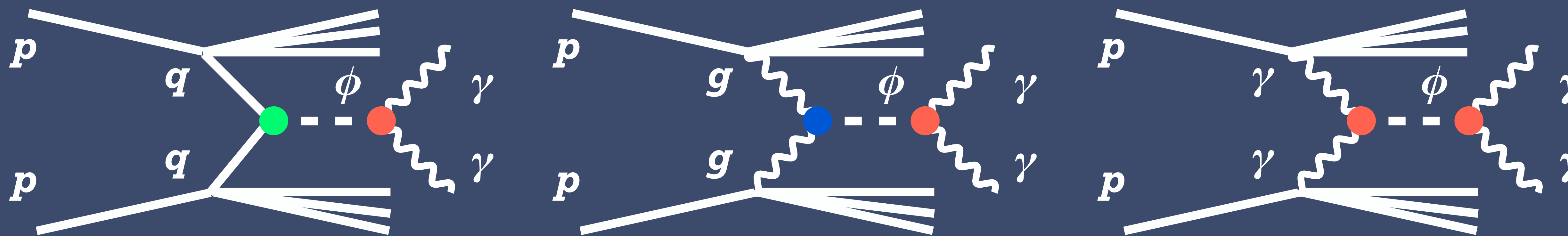

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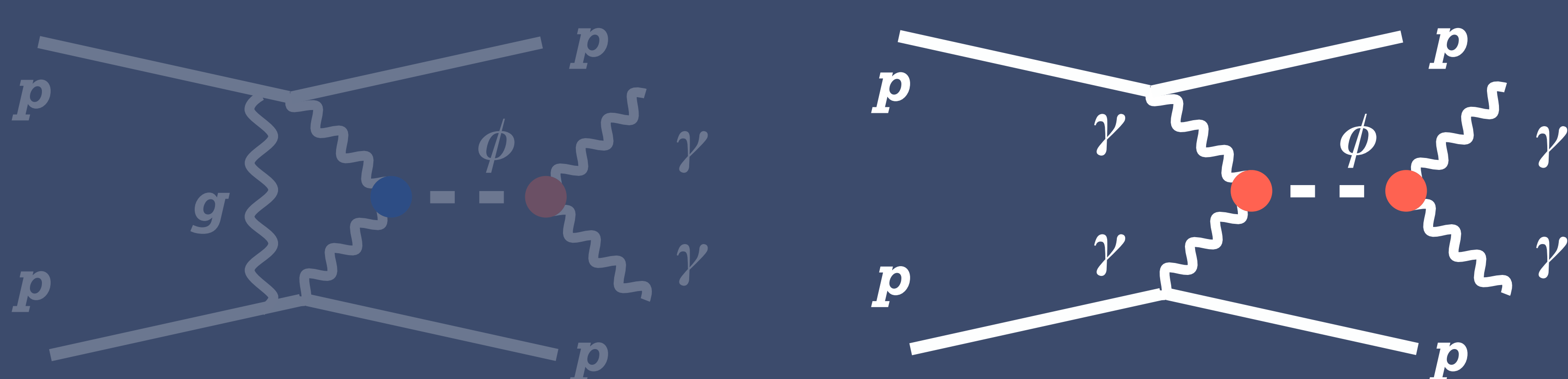

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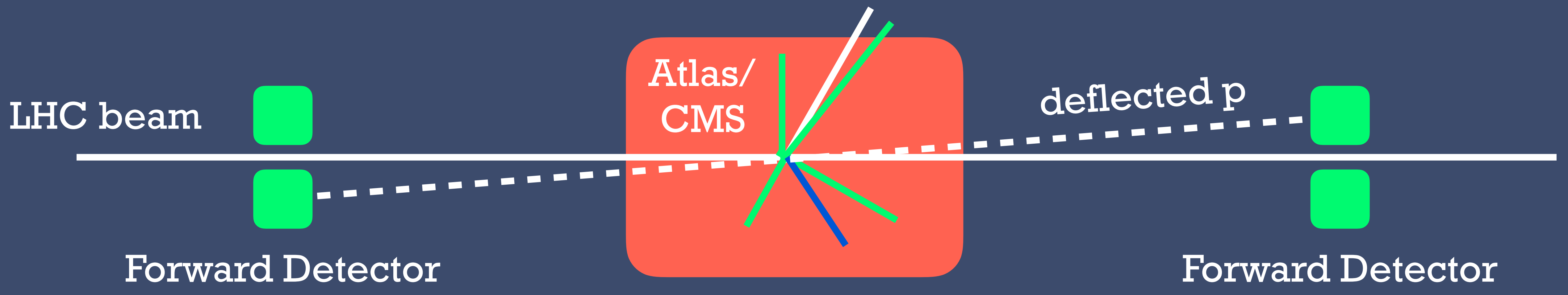

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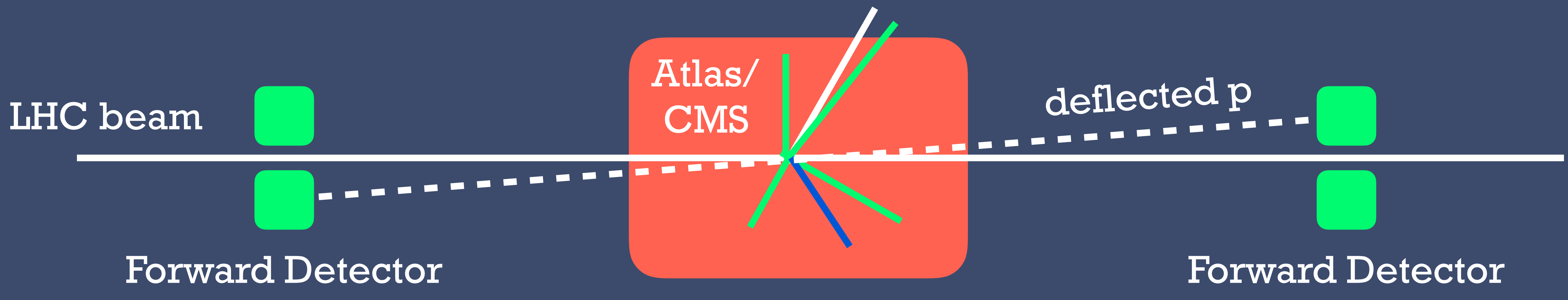

- All inelastic events can be completely rejected
- Essentially background-free (pile up under control)
- Installed in CMS, planned in ATLAS

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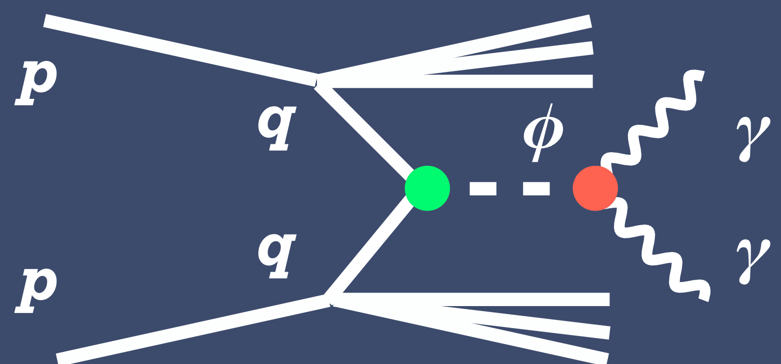

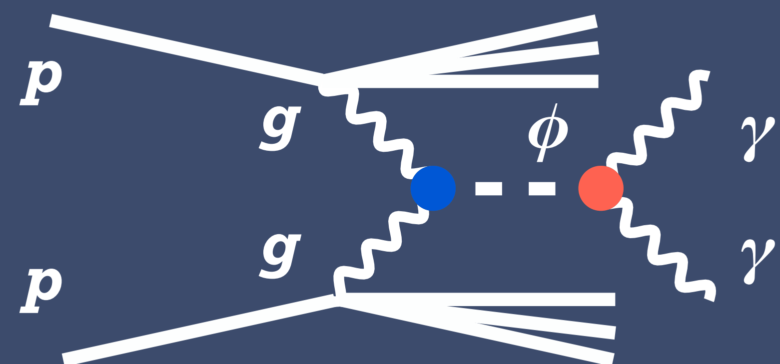

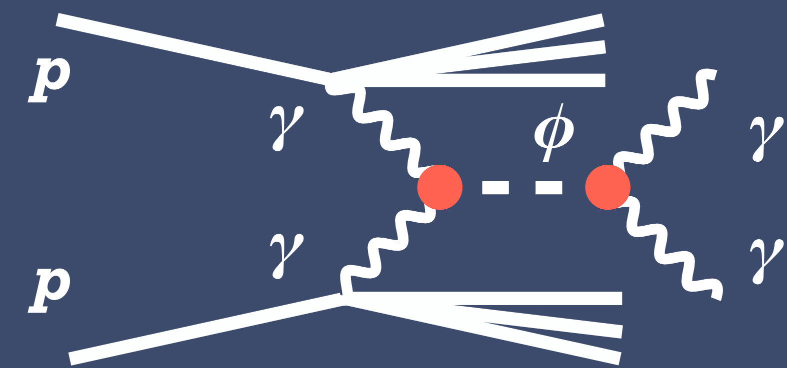

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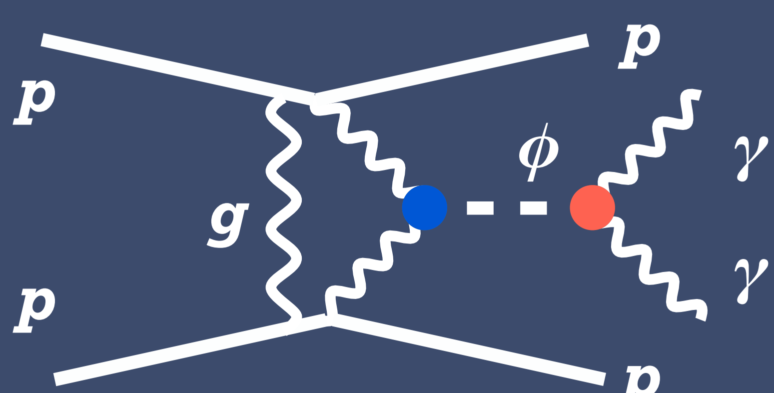

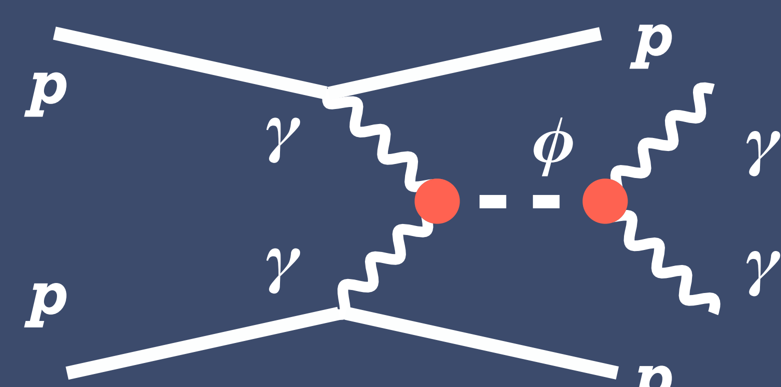

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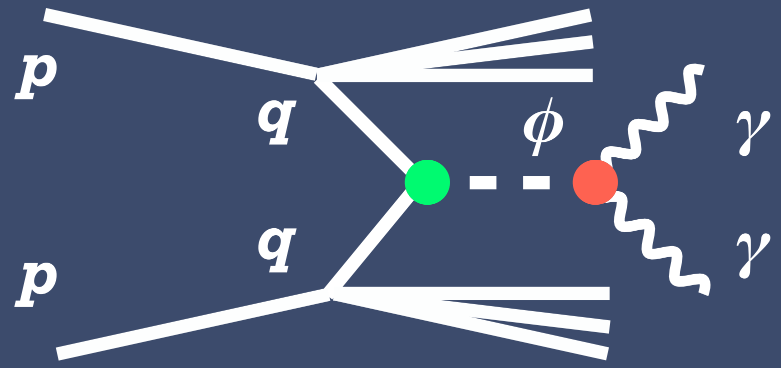

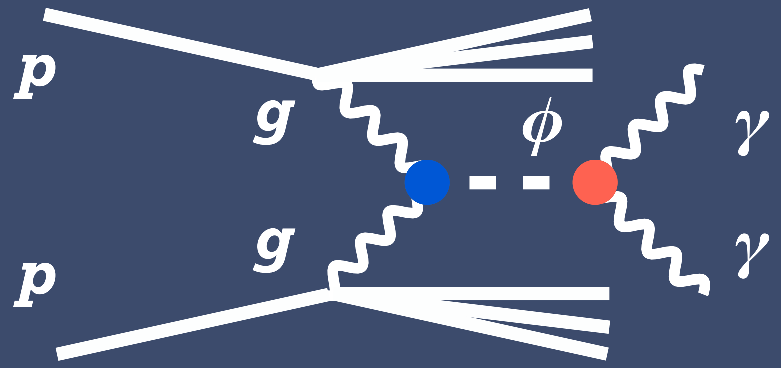

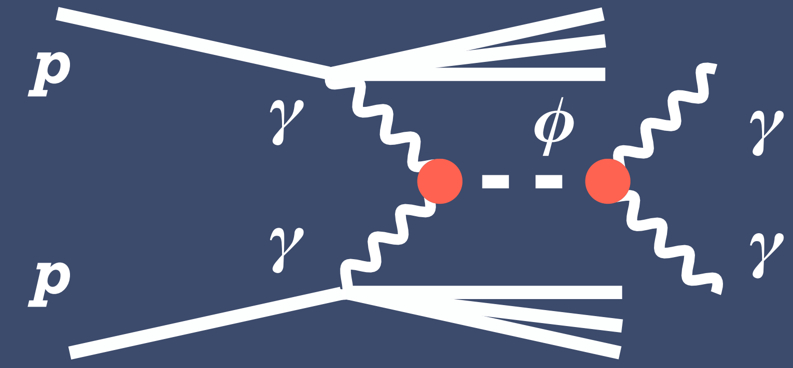

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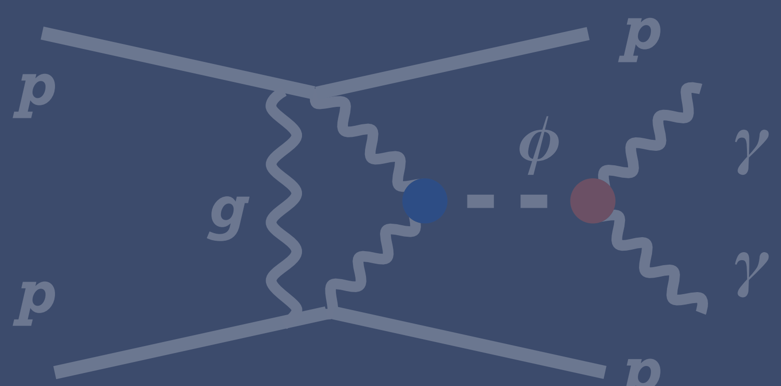

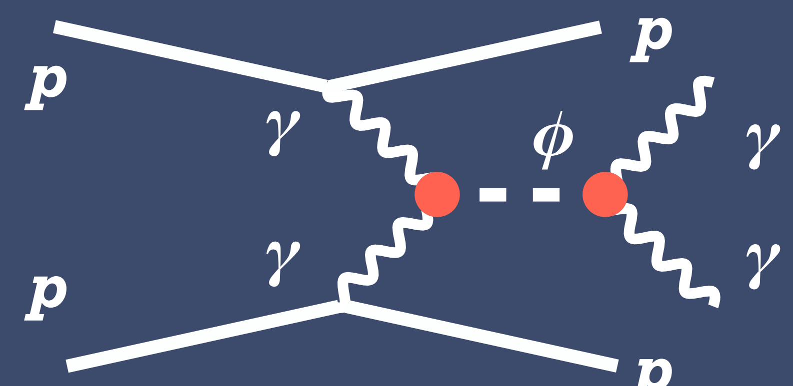

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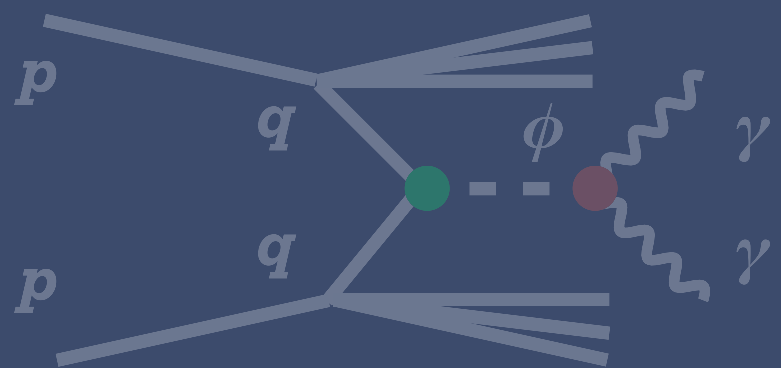

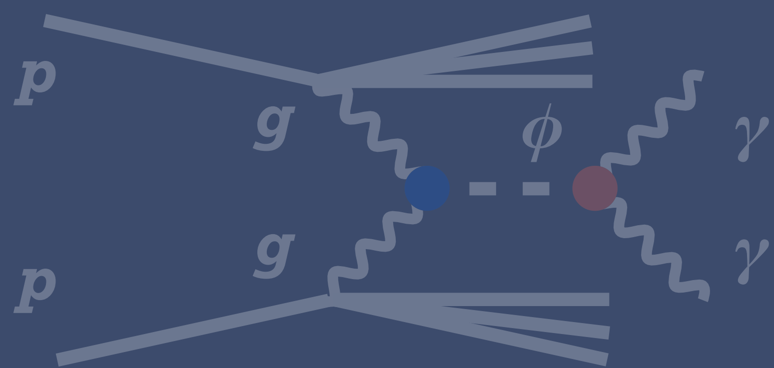

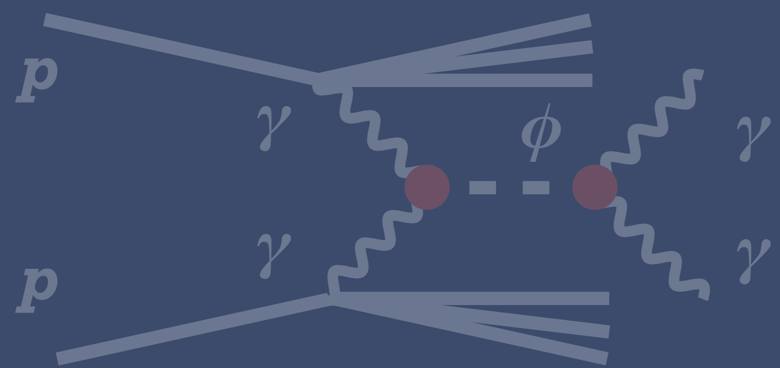

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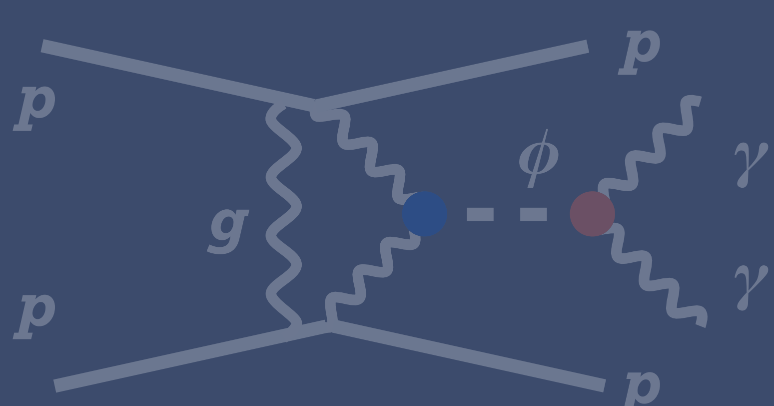

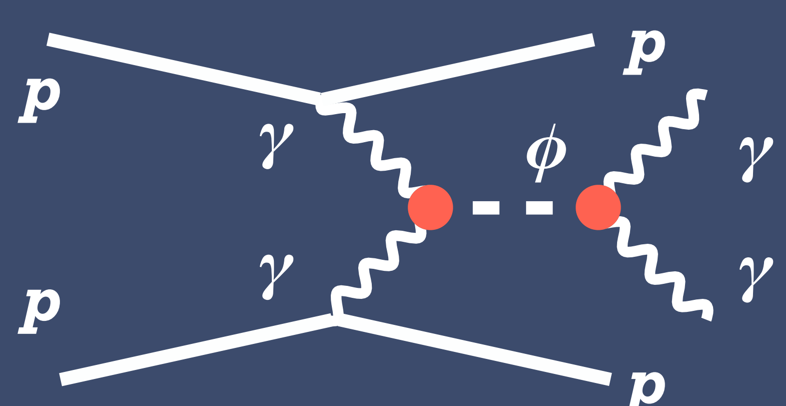

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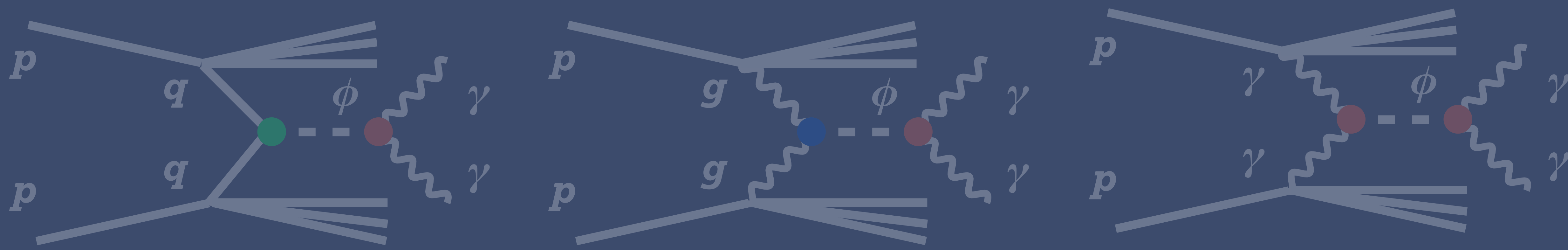

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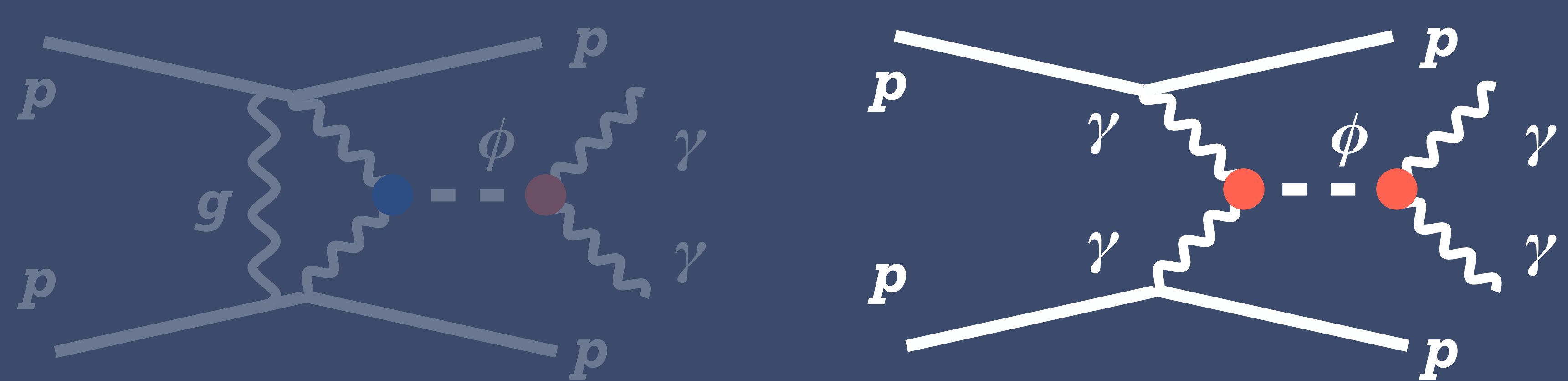

- Allows precision measurement of diphoton coupling!

Cross Section

- Elastic cross section under excellent theoretical control
- With realistic cuts the cross section is

$$\sigma_{pp\to\gamma\gamma pp} = 0.23\ \text{fb} \left(\frac{5\ \text{TeV}}{f_\gamma}\right)^4 \frac{45\ \text{GeV}}{\Gamma_\phi}$$

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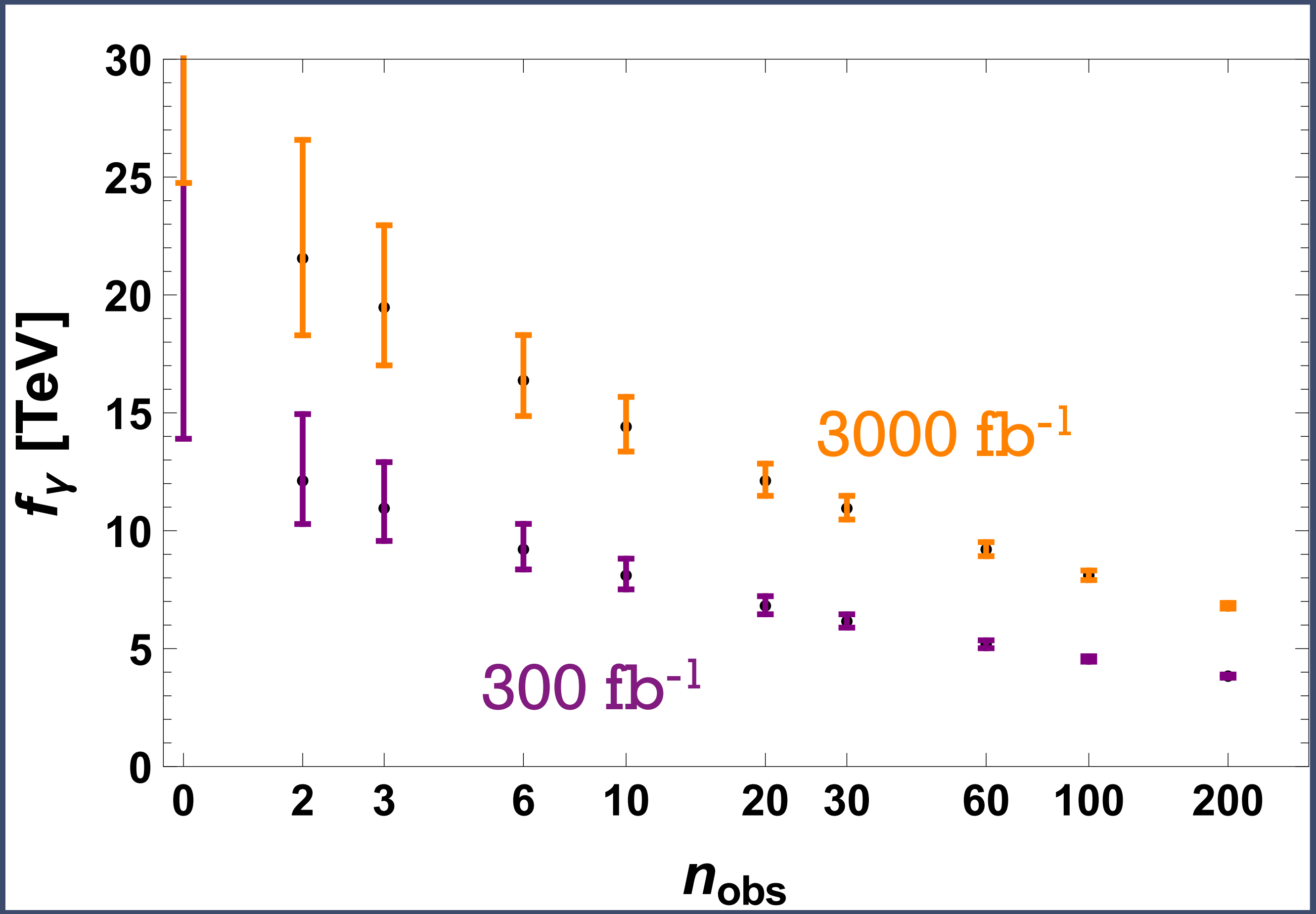

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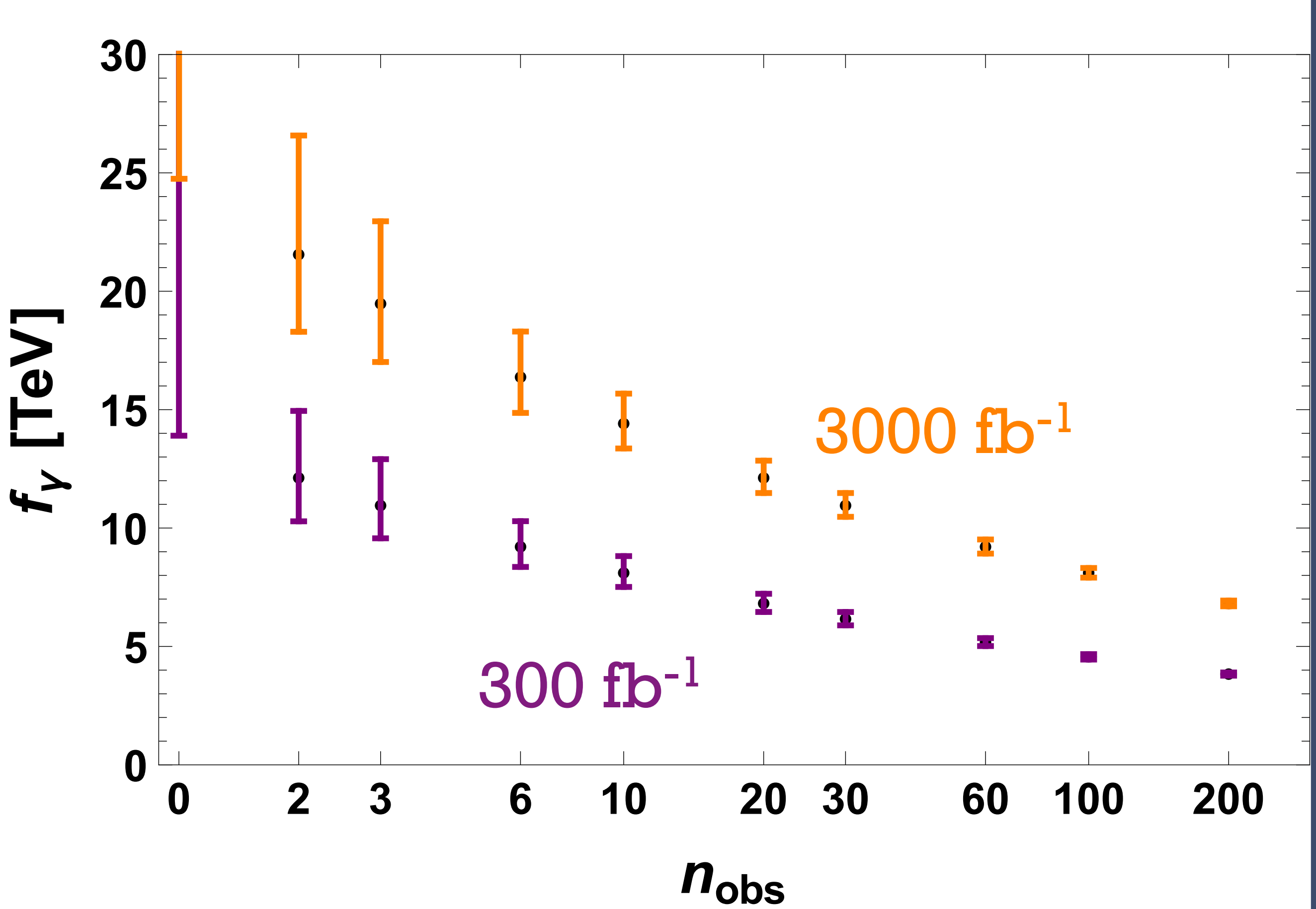
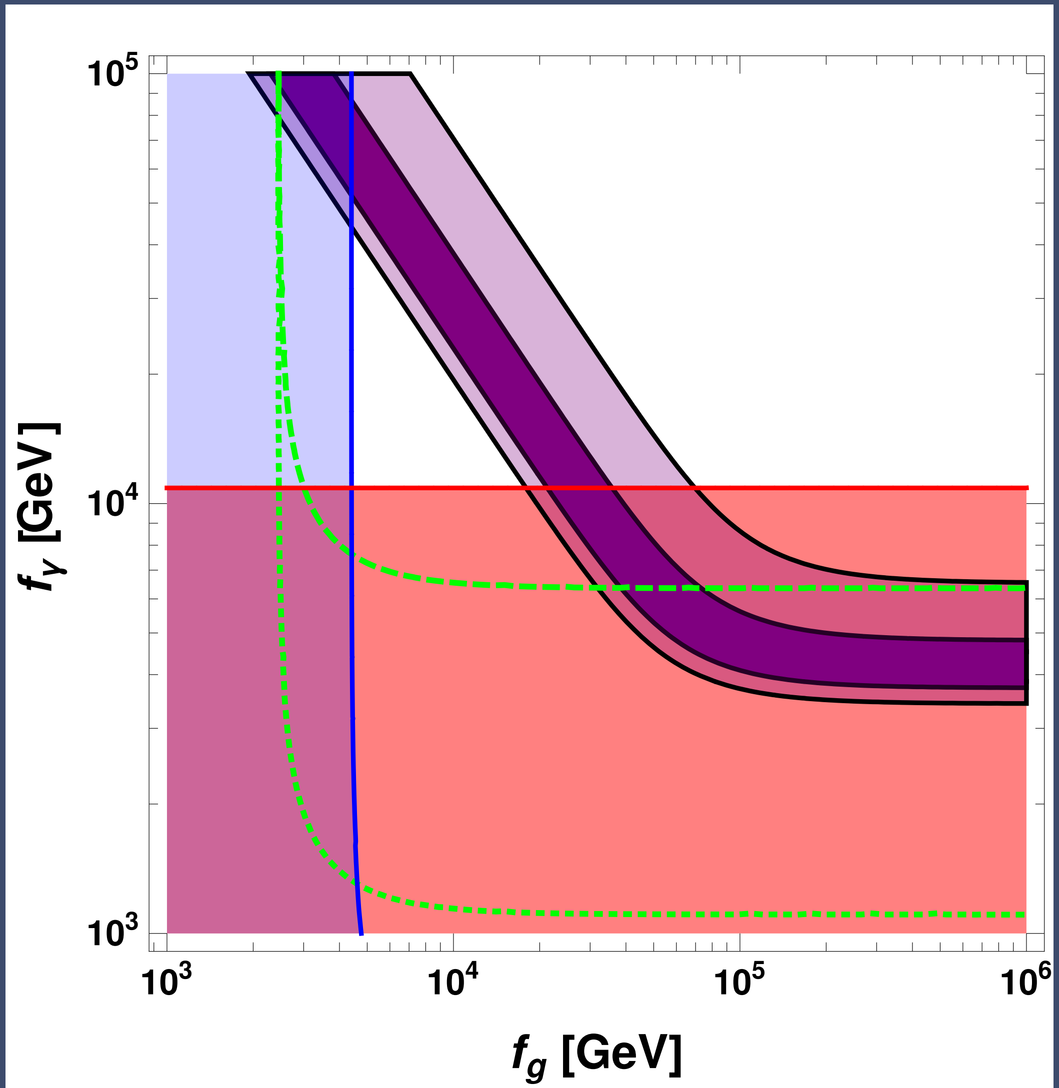


Exclusion power
at 68% (95%)

$f_\gamma > 14\ (11)$ TeV

$f_\gamma > 25\ (19)$ TeV

Gluon vs Photon Coupling



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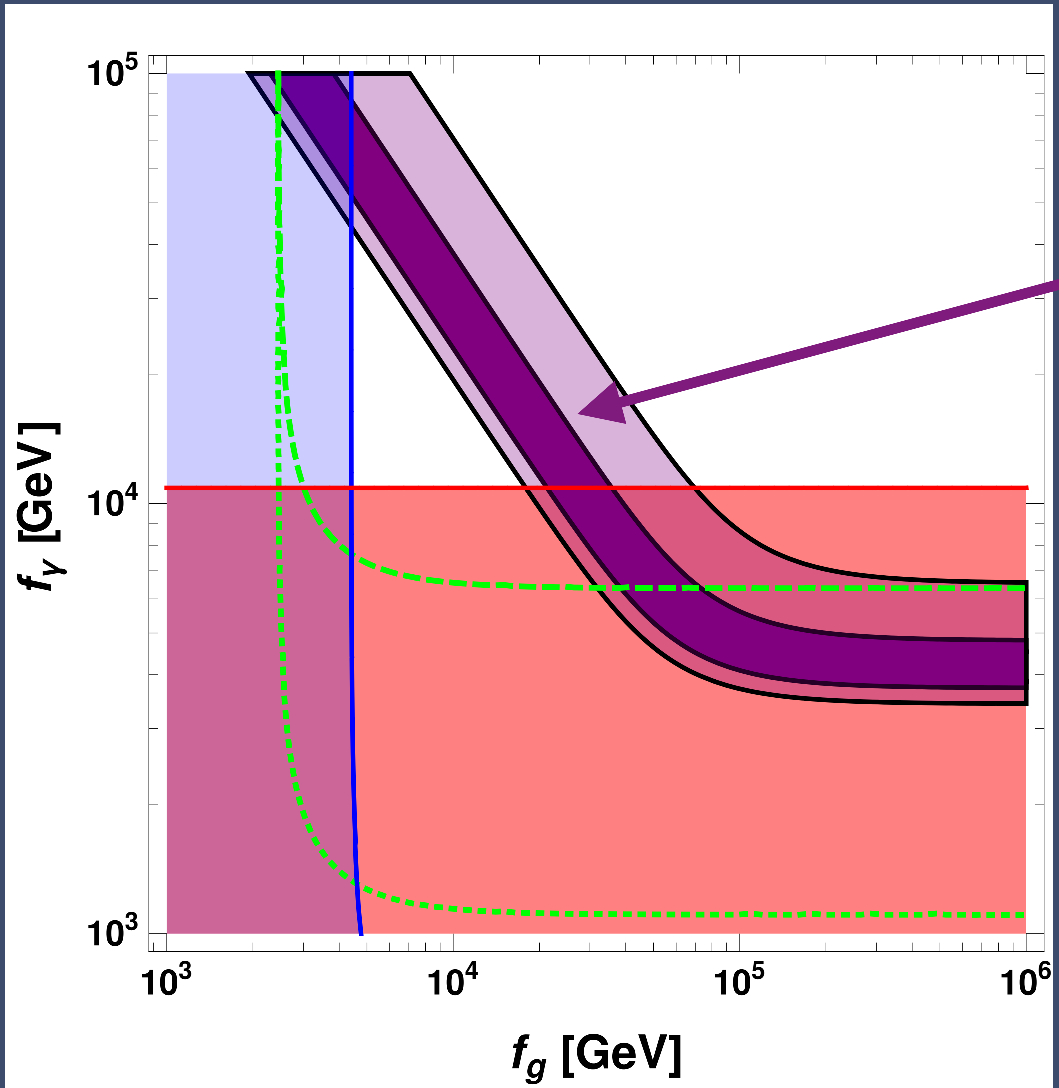
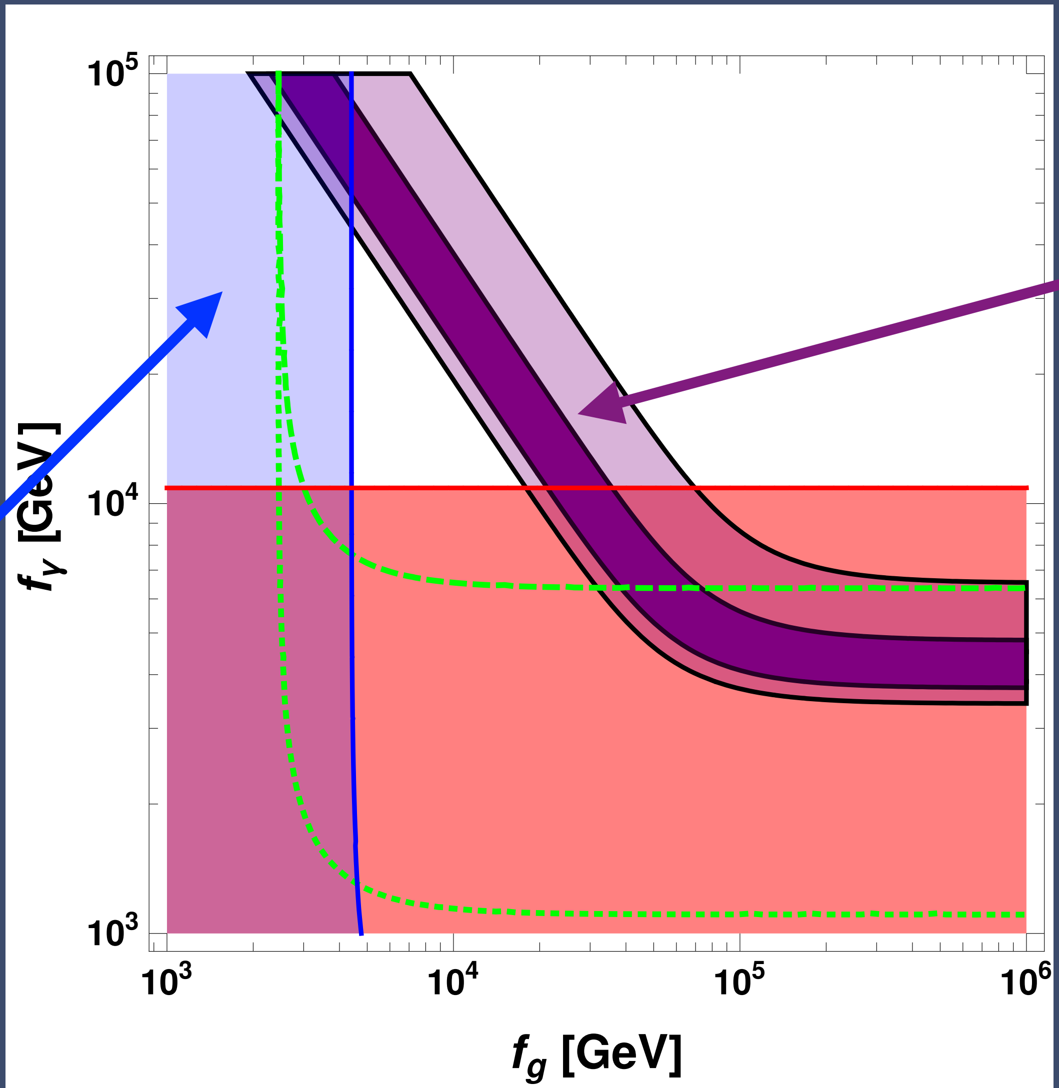


Region preferred by diphoton excess at Γ_ϕ = 45 GeV

Gluon vs Photon Coupling

Region excluded by Run - I (8 TeV) dijet searches



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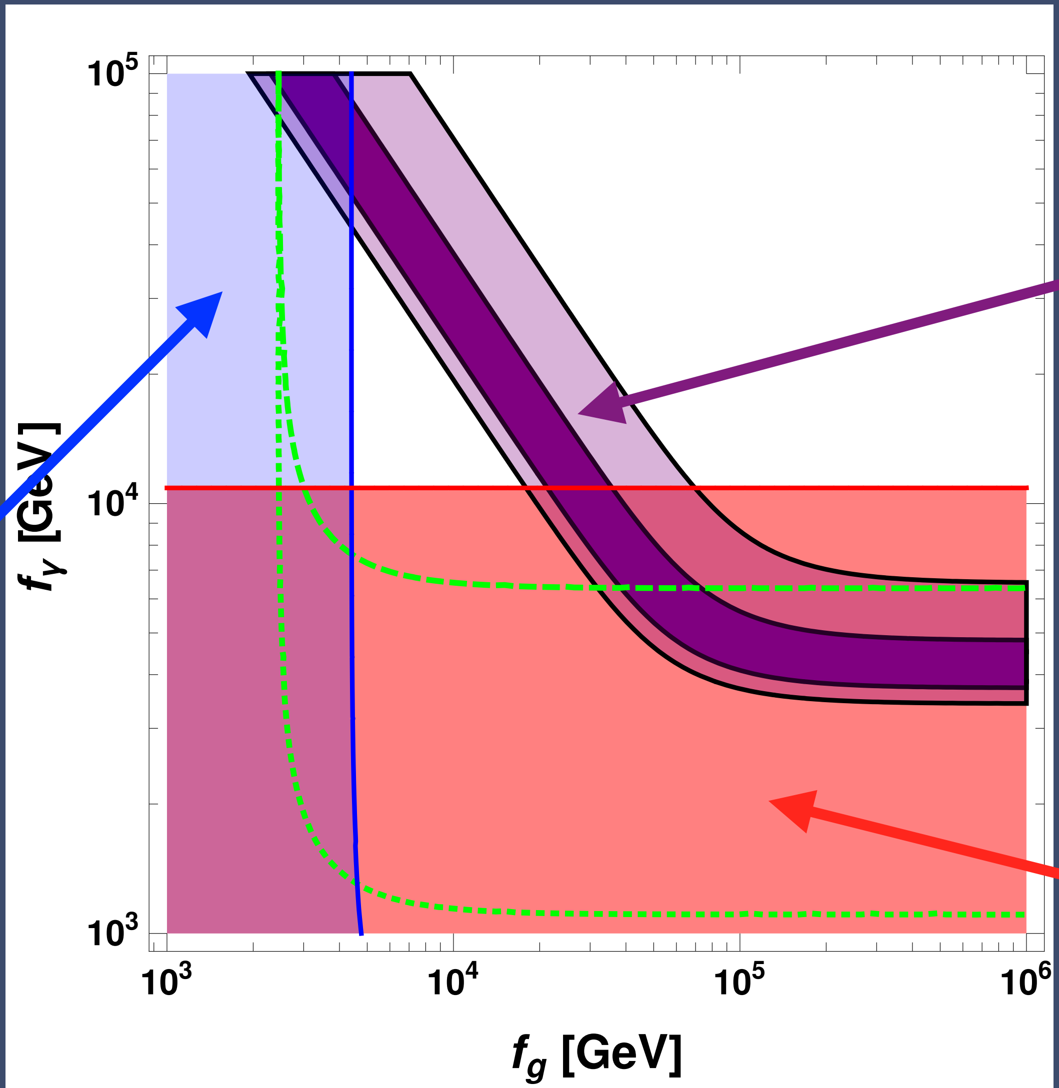

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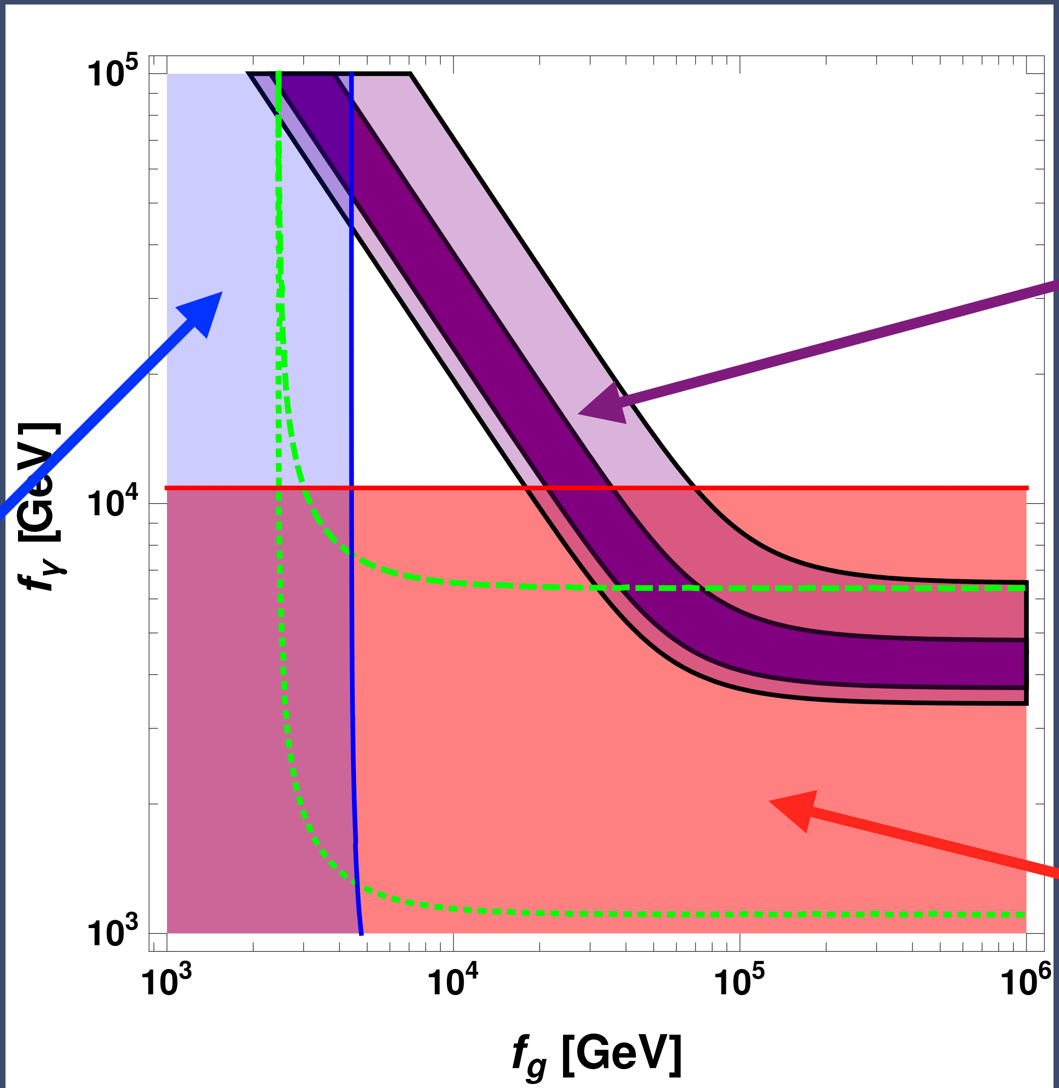

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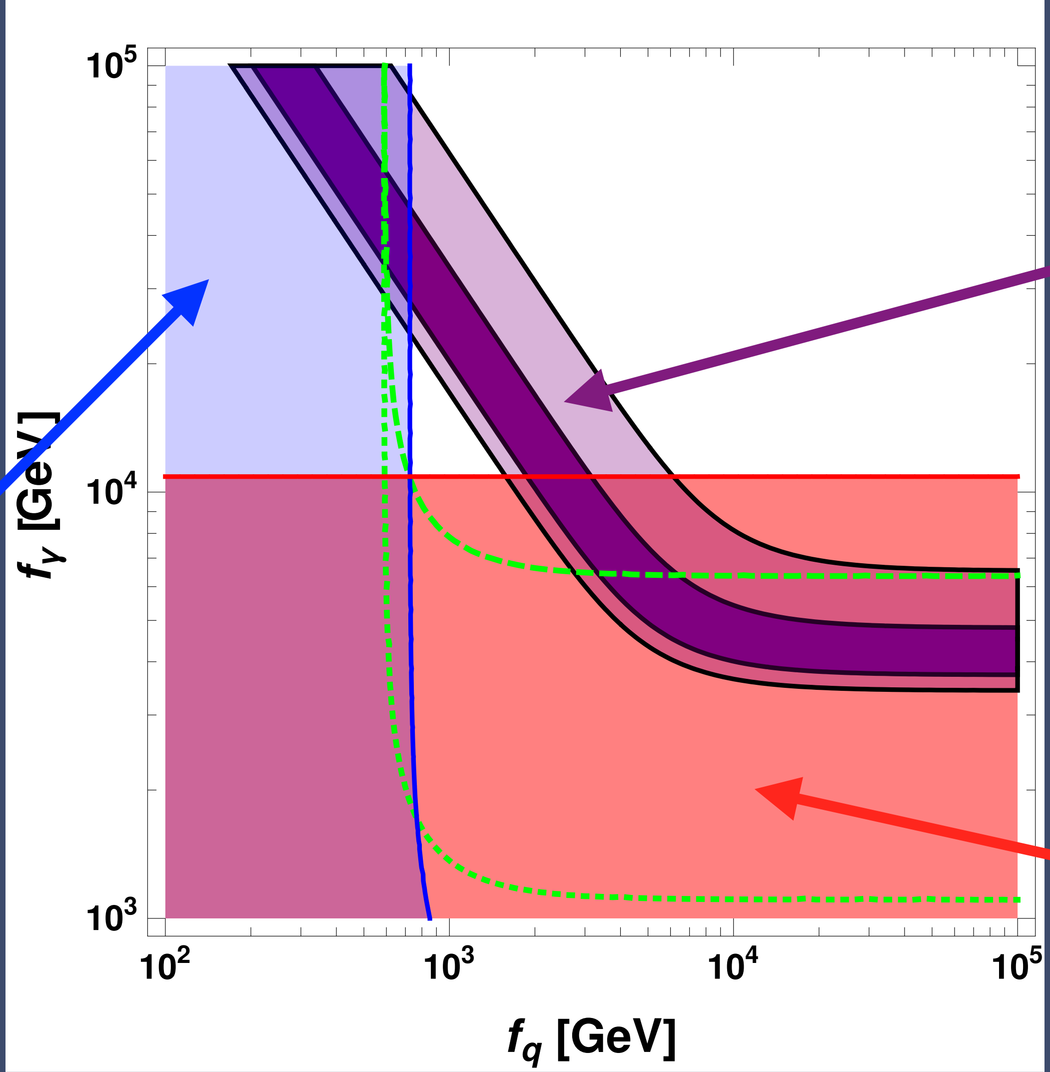
- Dijet searches and elastic γγ fusion are complementary
- More data will improve both bounds and can cover the entire region predicted by the diphoton excess

Quark vs Photon Coupling



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- Two parameters, express in terms of f_γ , $r = f_W / f_B$:

$$\mathcal{L}_{eff} = \frac{1}{f_\gamma}\phi\left(F^2_{\mu\nu} + \frac{2s_w c_w(r-1)}{c_w^2 r + s_w^2} Z_{\mu\nu}F^{\mu\nu} + \frac{s_w^2 r + c_w^2}{c_w^2 r + s_w^2} Z^2_{\mu\nu} + \frac{2}{c_w^2 r + s_w^2}|W_{\mu\nu}|^2\right)$$

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- Constraints on these couplings exist from run-1 diboson measurements

Constraints from gauge invariance

- Strongest constraint: Zγ

$$\sigma_{Z\gamma}^{8\ \mathrm{TeV}} = \sigma_{\gamma\gamma}^{13\ \mathrm{TeV}}\ \frac{\sigma_{\gamma\gamma}^{8\ \mathrm{TeV}}}{\sigma_{\gamma\gamma}^{13\ \mathrm{TeV}}}\ \frac{\Gamma_{Z\gamma}}{\Gamma_{\gamma\gamma}}$$

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lower limit (excess) — $\sigma^{13\ \text{TeV}}_{\gamma\gamma}$

function of r — $\frac{\Gamma_{Z\gamma}}{\Gamma_{\gamma\gamma}}$

upper limit (run I) — $\sigma^{8\ \text{TeV}}_{Z\gamma}$

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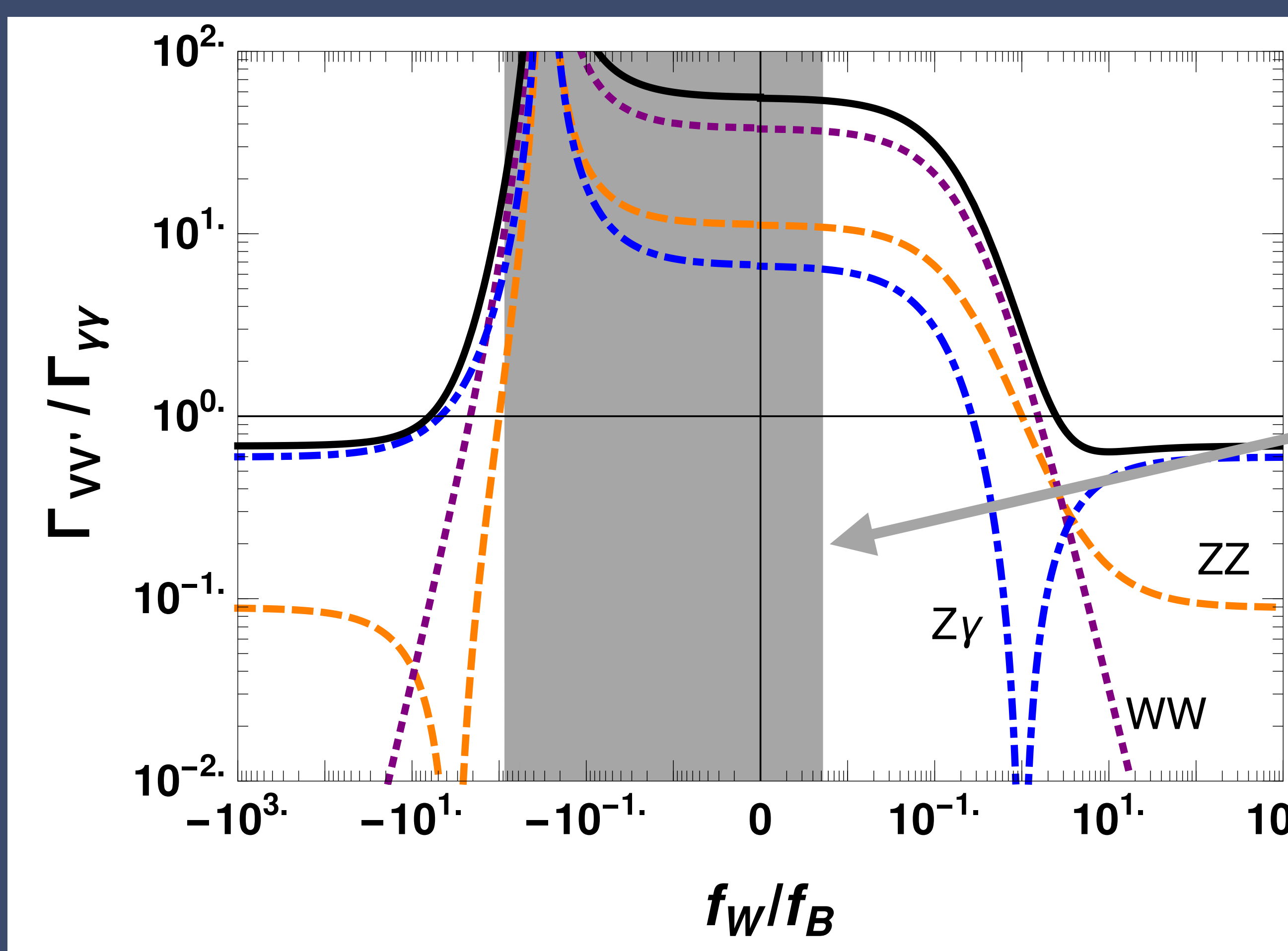

Region of $r = f_W / f_B$ Excluded by 8 TeV Zγ search

CONCLUSIONS

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BACKUP