Measuring Coloron Couplings

Through Associated Production with W Boson at the LHC

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with

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Introduction

Entering discovery era with the LHC

- Friendly with strong dynamics $\rightarrow$ new colored particles
  colorons, axigluons, Kaluza-Klein gluons, Techni-rhos, ...
- Measuring properties of particle if discovered: mass, couplings, ...

Introduction

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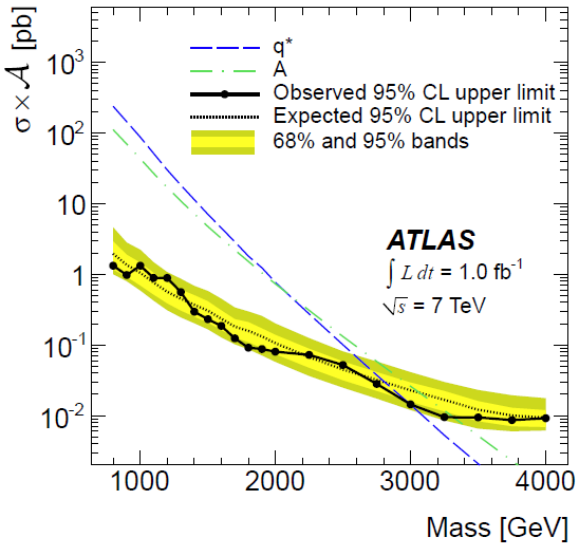
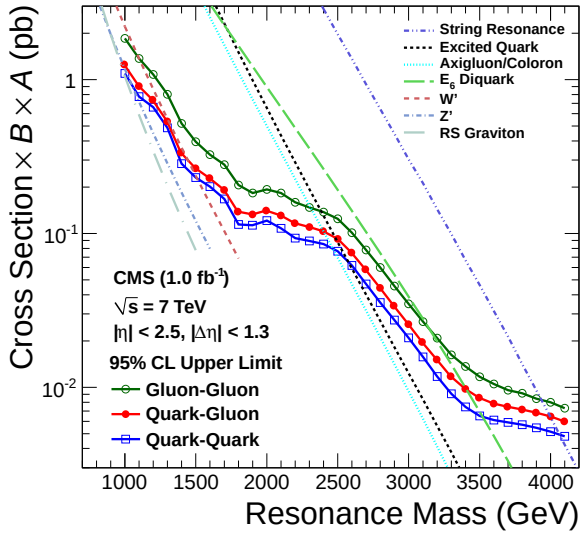
Massive color-octet vector bosons: Colorons/Axigluons

Hill, Parke (1993) / Frampton, Glashow (1987)

- Explains Tevatron $t\bar{t}$ forward-backward Asymmetry
- Decay to light quarks $\rightarrow$ can be discovered via dijet resonance



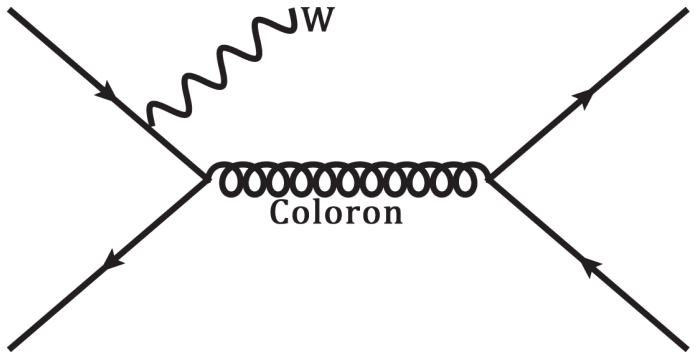
ATLAS Collaboration (2012)



CMS Collaboration (2011)

Goal

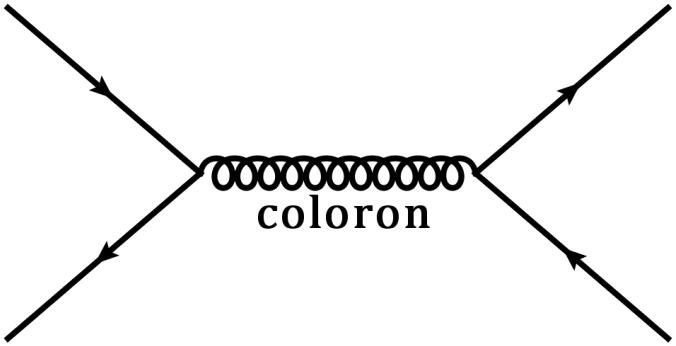
Associated production with W



Measurement

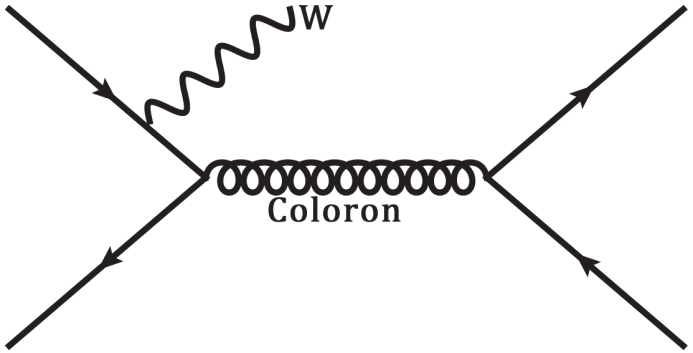
Goal

Dijet



Discovery

Associated production with W



Measurement

Goal

" Using associated production* with W and dijet resonance to determine colorons/axigluons couplings."

*Idea introduced by Cvetic and Langacker (1992) for measuring Z' couplings

Minimal Model $SU(3) \times SU(3) \to SU(3)_C$

- Allows flavor universal and non-universal charge assignments

$$\underbrace{g_s \bar{q} C^\mu \gamma_\mu \left(g_V^q + g_A^q \gamma_5\right) q}_{q=u,d,c,s} \quad \text{and} \quad \underbrace{g_s \bar{T} C^\mu \gamma_\mu \left(g_V^T + g_A^T \gamma_5\right) T}_{T=t,b}$$

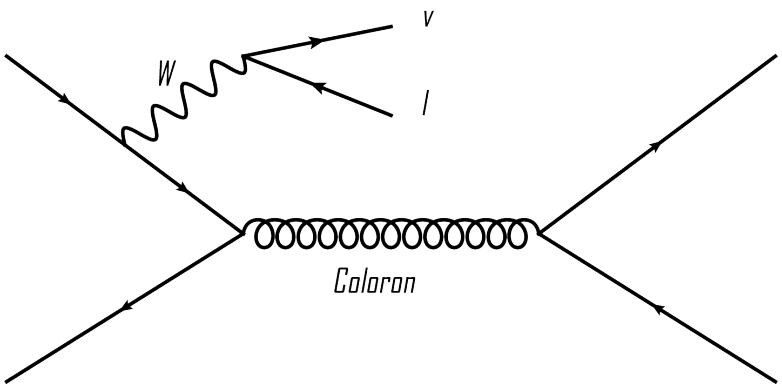
Enhances top forward-backward asymmetry

$$g_V^T = g_V^q, \qquad g_A^T = -g_A^q$$

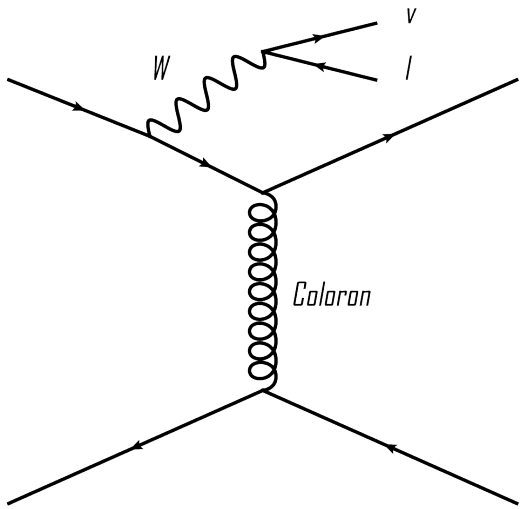
Ferrario and Rodrigo (2009)

Signals: Associated Production with W

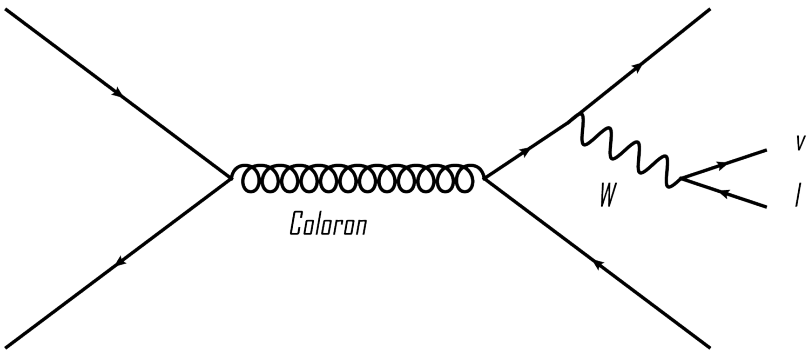
Study colorons with masses 2.5 TeV to 4.5 TeV with a *leptonic-decayed W* boson at 14 TeV LHC.



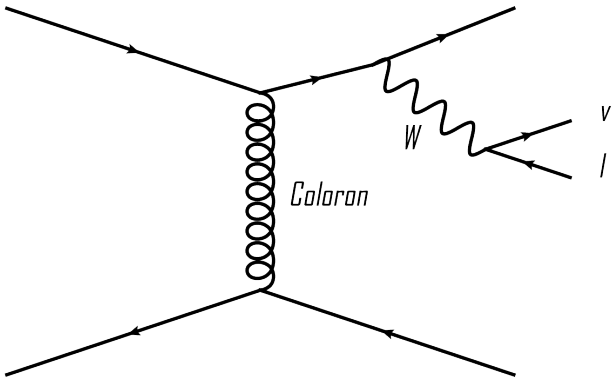
s-channel, Initial-state W



t-channel, Initial-state W



s-channel, Final-state W



t-channel, Final-state W

Backgrounds (Standard Model)

- $W(\rightarrow l\nu)$ + jets

- Semileptonic $t\bar{t}$ + jets
- Z $(\rightarrow ll)$ + jets
- singletop (leptonic)

- WW $(\rightarrow l\nu, jj)$ + jets
- WZ $(\rightarrow l\nu, jj)$ + jets
- ZZ $(\rightarrow ll, jj)$ + jets (missing lepton)
- ZW $(\rightarrow ll, jj)$ + jets
- WZ $(\rightarrow l\nu, \nu\nu)$ + jets
- Leptonic $t\bar{t}$ + jets (missing lepton)
- Hadronic $t\bar{t}$ + jets (isolated lepton)

Backgrounds (Standard Model)

Leading

- $W(\to l\nu)$ + jets

Sub-leading

- Semileptonic $t\bar{t}$ + jets
- $Z\ (\to ll)$ + jets
- singletop (leptonic)

Insignificant after cuts

- $WW\ (\to l\nu, jj)$ + jets
- $WZ\ (\to l\nu, jj)$ + jets
- $ZZ\ (\to ll, jj)$ + jets (missing lepton)
- $ZW\ (\to ll, jj)$ + jets
- $WZ\ (\to l\nu, \nu\nu)$ + jets
- Leptonic $t\bar{t}$ + jets (missing lepton)
- Hadronic $t\bar{t}$ + jets (isolated lepton)

Event Generation and Event Selection

Event Generation: MadGraph 5.1.3 $\rightarrow$ Pythia 6.4 $\rightarrow$ PGS4

Event Selection ("Basic cuts"):

- At least two isolated jets
  - $p_T > 40\,\mathrm{GeV}$
  - $|\eta| < 2.5$
  - $\Delta R_{jj} > 0.4$
- One isolated electron or muon
  - $p_T > 25\,\mathrm{GeV}$
  - $|\eta| < 2.5$
  - $\Delta R_{jl} > 0.4$, $\Delta R_{ll} > 0.2$
- Missing energy $> 25\,\mathrm{GeV}$

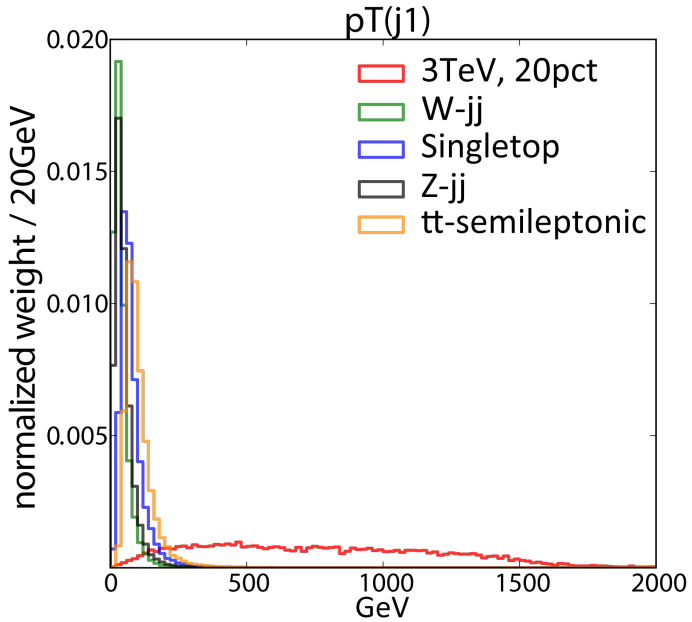
Optimization:

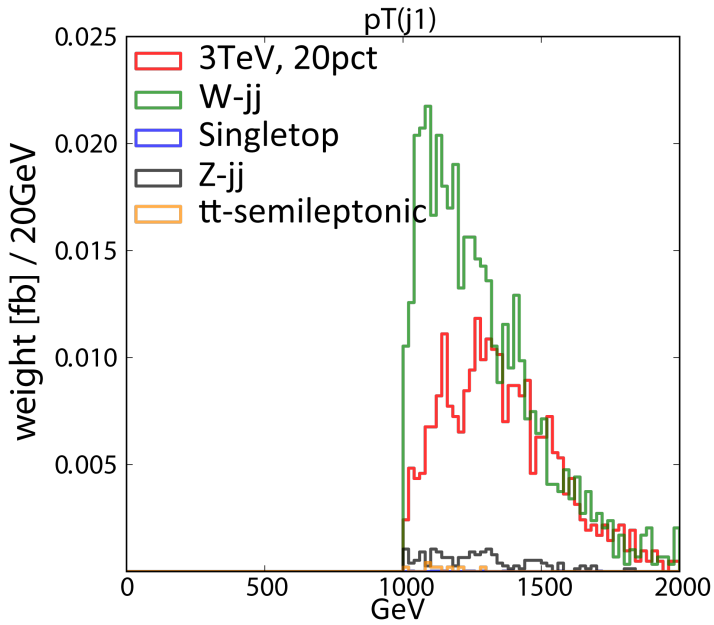
- p_T of leading jets
- Total transverse jet energy $H_T \simeq \sum p_T$
- Invariant masss m_{jj} or mT_{jjW}

"Counting experiment": Maximize significance $\simeq \frac{s}{\sqrt{b}}$ at $10\,fb^{-1}$ and $100\,fb^{-1}$ for LHC $14\,\mathrm{TeV}$, requiring at least 10 events.

Only p_T of the two leading jets are hard - they are "encoded" in H_T and $m(jj)$ or $m_T(jjW)$.

Optimization





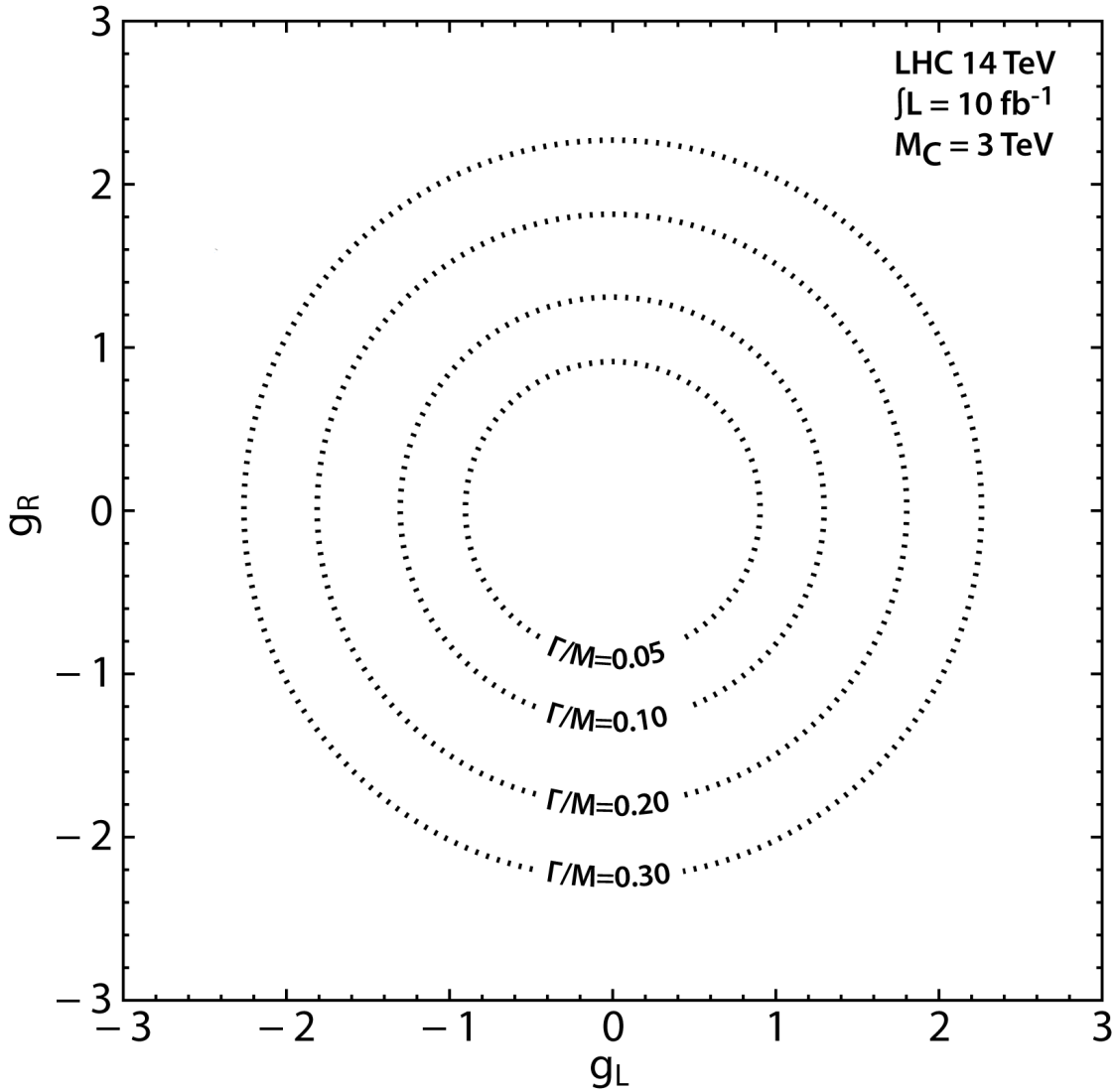
Number of events for $3\,\mathrm{TeV}$ **coloron with** $\Gamma/M = 0.2$, $g_V = 1.3$, $g_A = 0$ **at** $14\,\mathrm{TeV}$, $10\,\mathrm{fb}^{-1}$**:**

process	basic cuts	$pT_{j1} >$ 1000 GeV	$pT_{j2} >$ 950 GeV
signal	250	82	52
Wjj	2.1×10^6	240	84
$t\bar{t}$	240×10^3	4	0
single-t	68×10^3	1	0
Zjj	48×10^3	7	4

Significance $\simeq 5.5$

Wjj with 3 TeV coloron/axigluon

- Width:
  $\frac{\Gamma}{M} \simeq \alpha_s \left(g_V^2 + g_A^2\right)$
  $\simeq \frac{\alpha_s}{2} \left(g_L^2 + g_R^2\right)$



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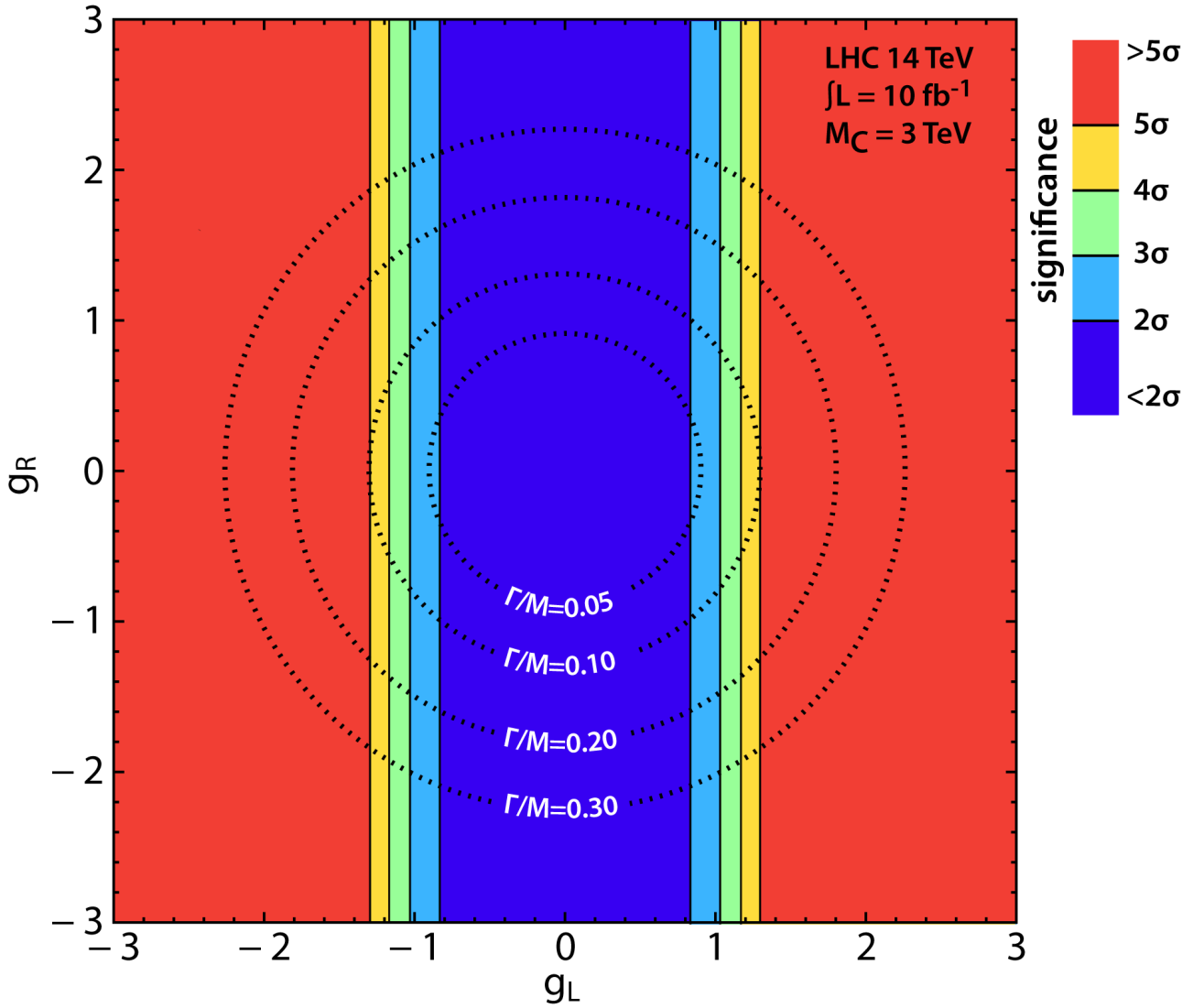

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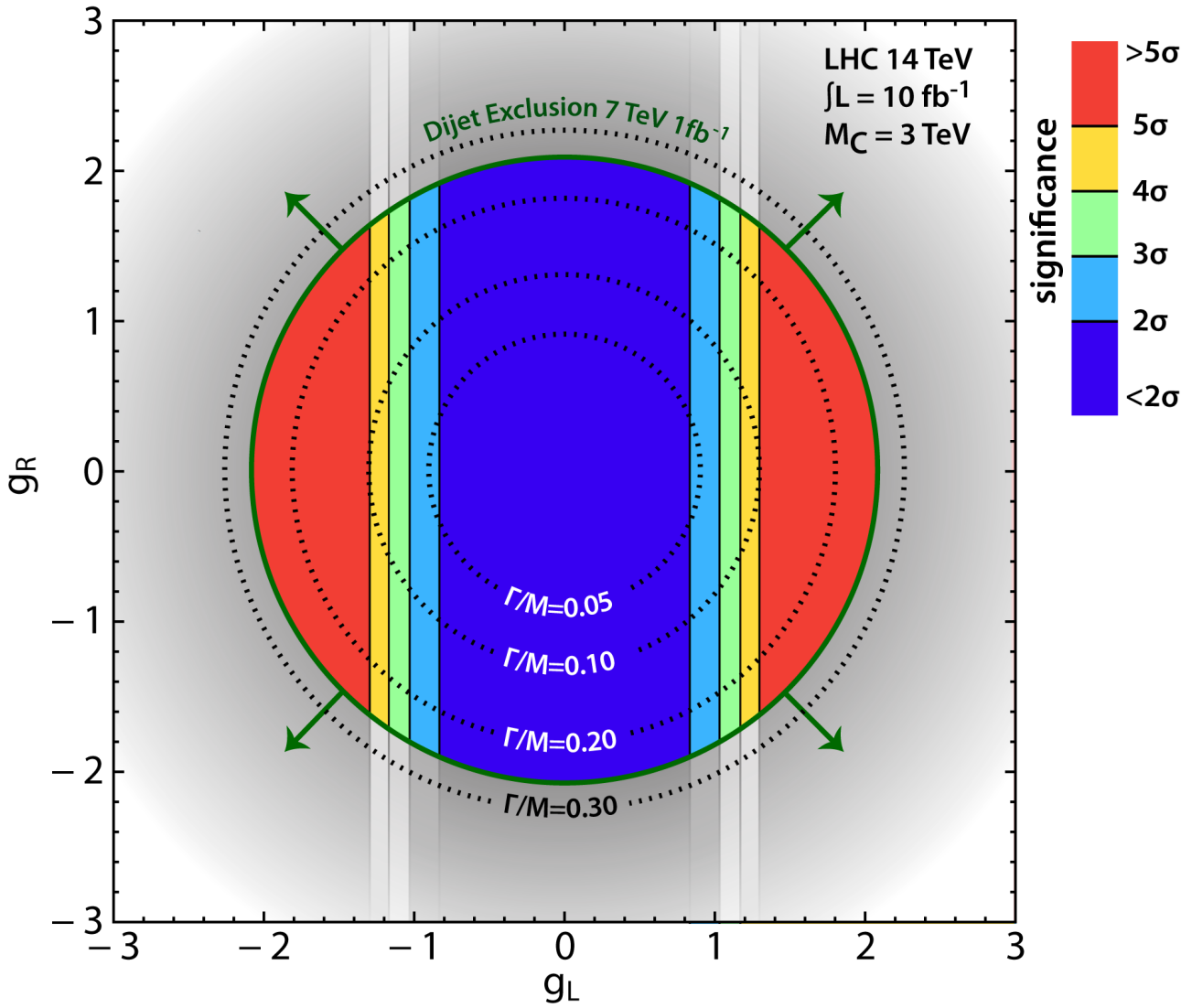
- significance $\simeq \frac{s}{\sqrt{b}}$
- Dijet exclusion at $7\,\mathrm{TeV}$, $1\,\mathrm{fb}^{-1}$
  CMS (2011): search for narrow width - does not constraint broad one.
  [Bai, Hewett, Kaplan, Rizzo (2011)]



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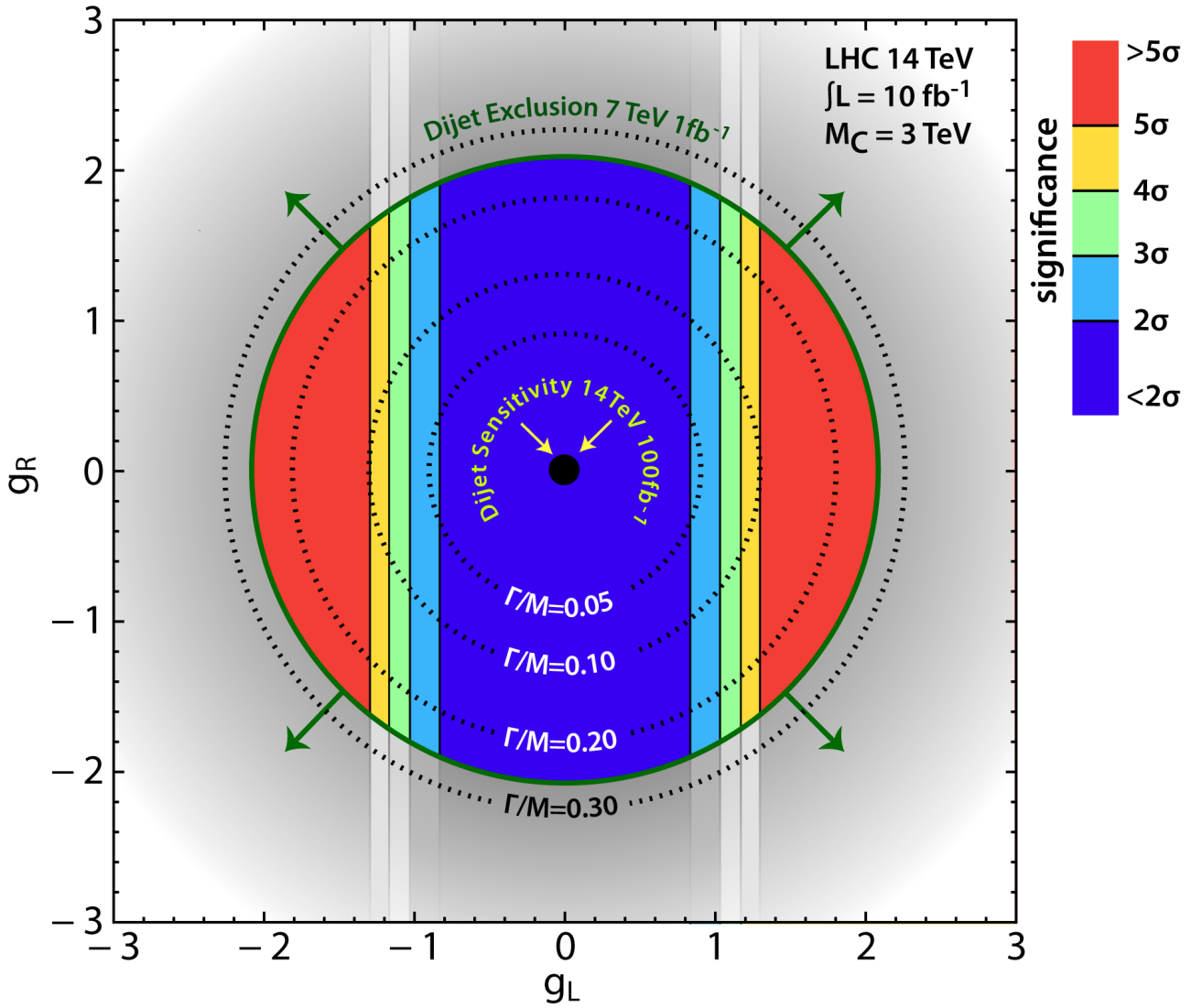
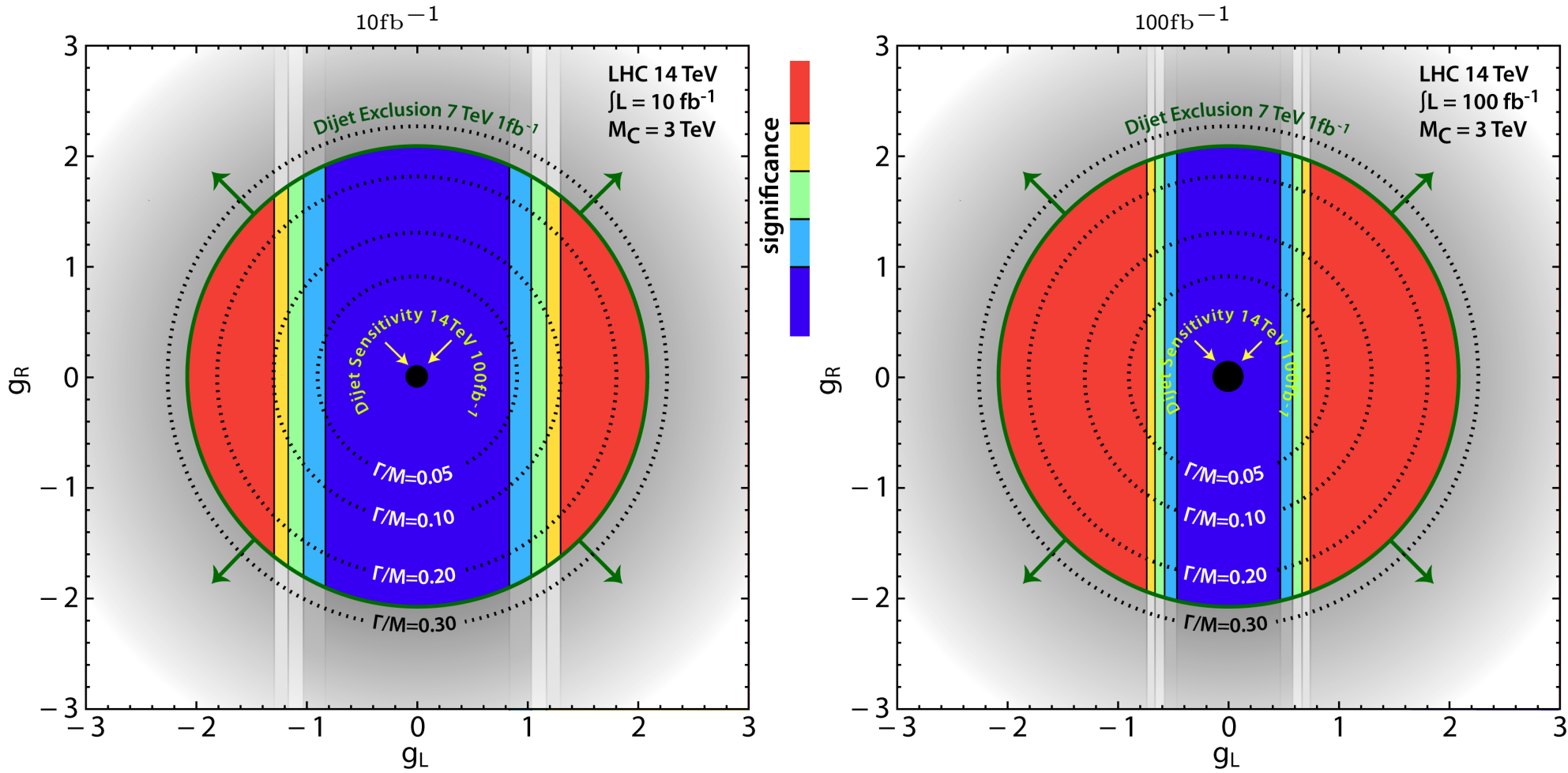
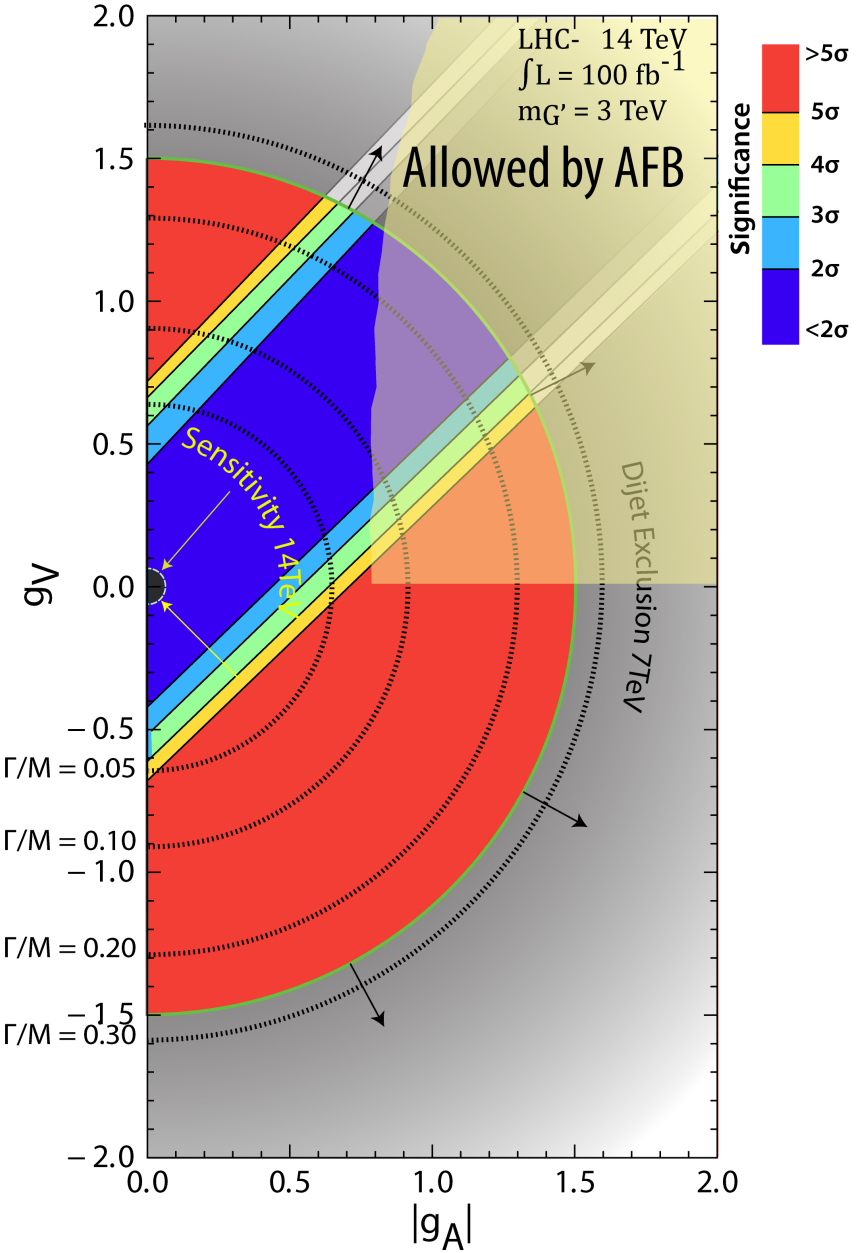
  [Bai, Hewett, Kaplan, Rizzo (2011)]
- Sensitivity at $14\,\mathrm{TeV}$, $100\,\mathrm{fb}^{-1}$
  [Scaled from CMS-NOTE 2006-070]



Wjj with 3 TeV coloron/axigluon: $10\,\mathrm{fb}^{-1}$ vs $100\,\mathrm{fb}^{-1}$



Wjj: Constraint from Tevatron $A_{FB}^{t\bar{t}}$



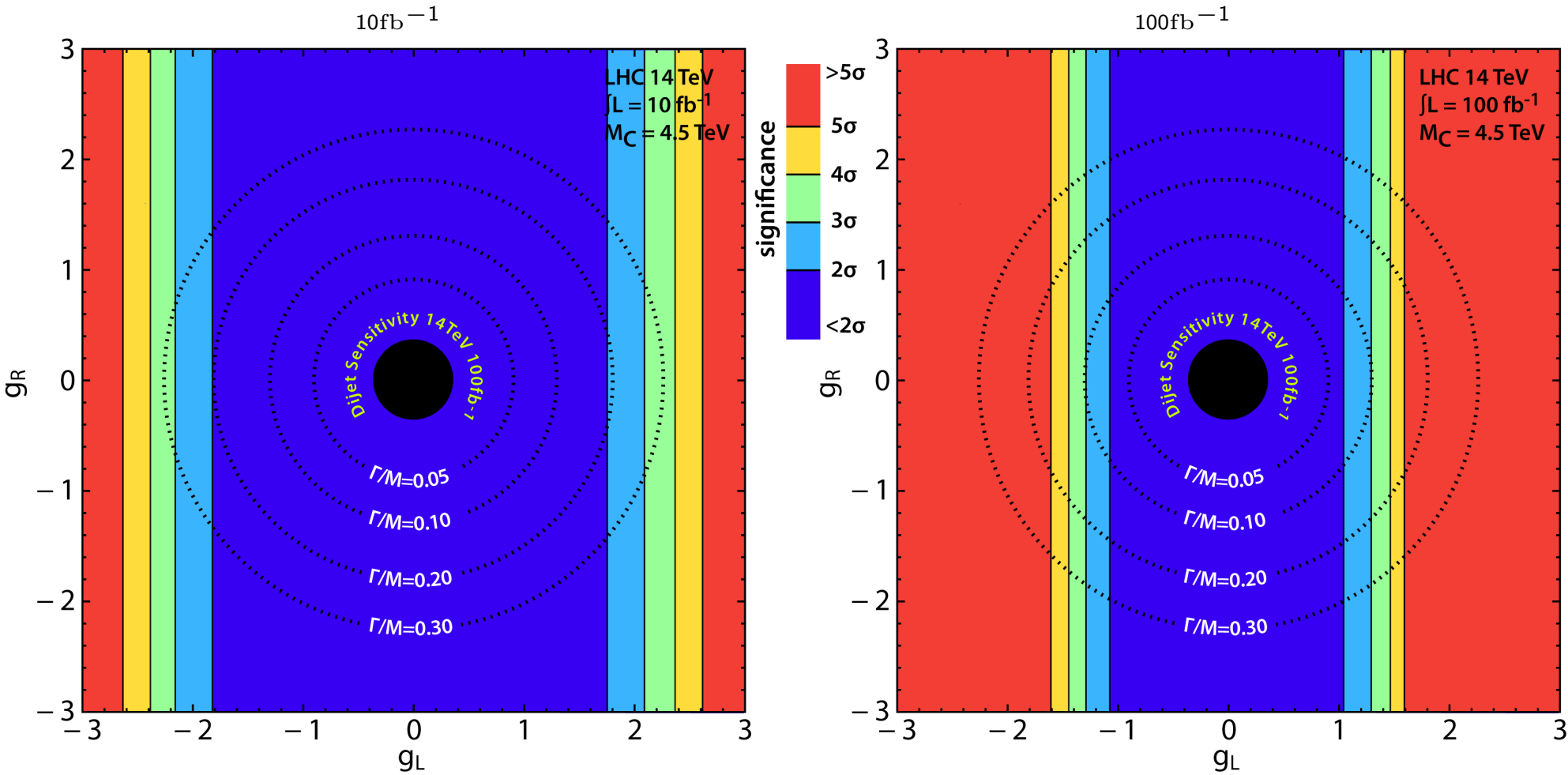
- Observed at CDF ($5.3\,\mathrm{fb}^{-1}$) and at D0 (at $5.4\,\mathrm{fb}^{-1}$)

  CDF Collaboration (2011), D0 Collaboration (2011)

- Analysis by Ferrario and Rodrigo (2010) shows region giving sufficient asymmetry for

$$g_V^t = g_V^q, \qquad g_A^t = -g_A^q$$

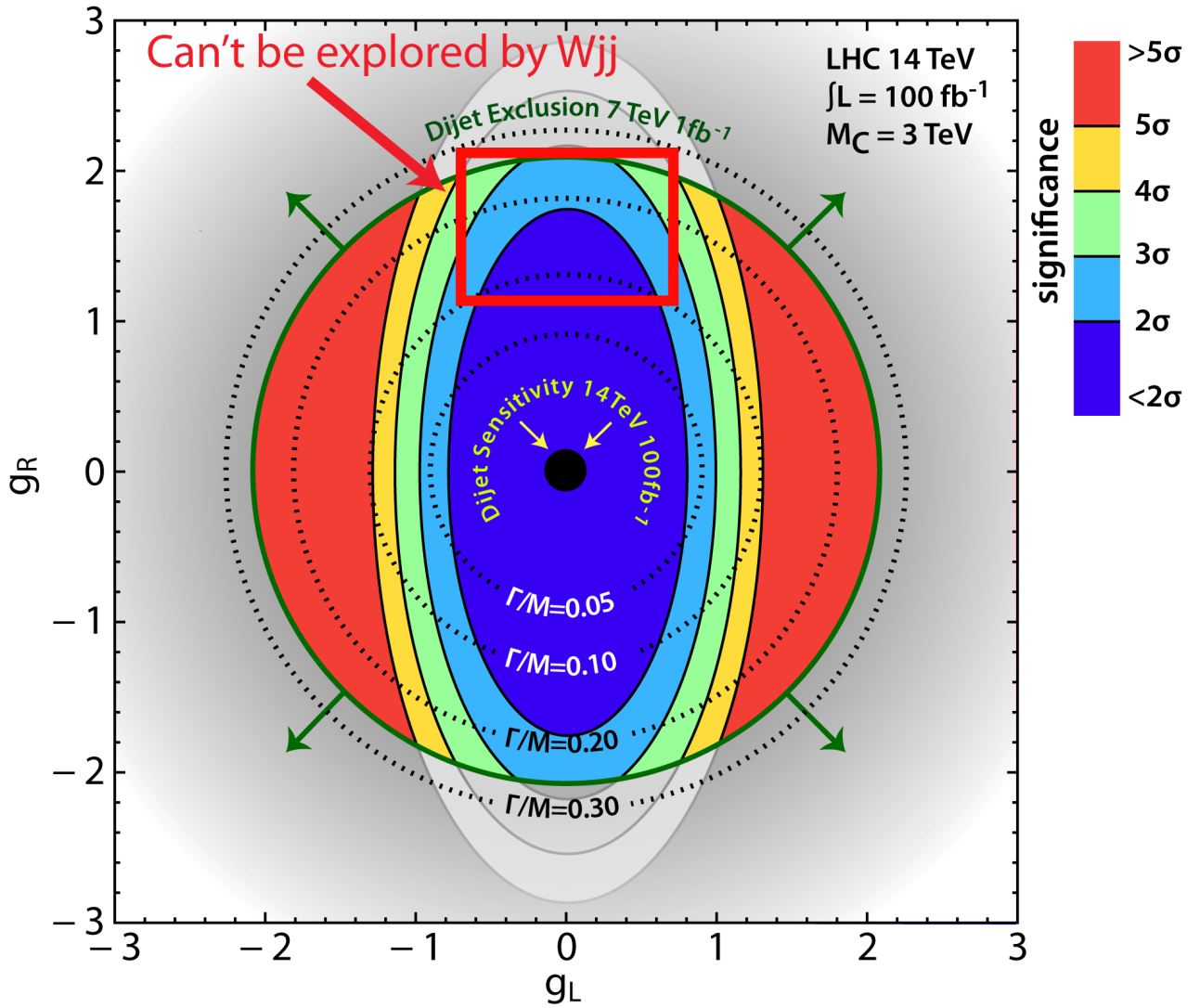
Reach: Wjj with 4.5 TeV coloron/axigluon



Complementary Info: Associated Production with Z-boson

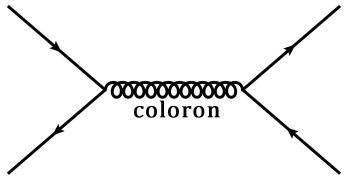
Leptonic-decayed Z
Compared with the "Wjj" case:

- Using similar event selection.
- More sensitive (only SM Zjj dominates)
- Helpful for region with $g_L \simeq 0$ ($g_V \simeq g_A$)

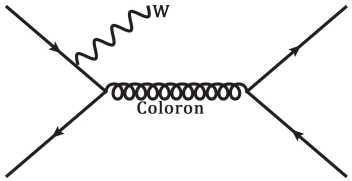


Conclusions

- Assume the discovery
- Dijet results + asosciated production W/Z
- Measure couplings

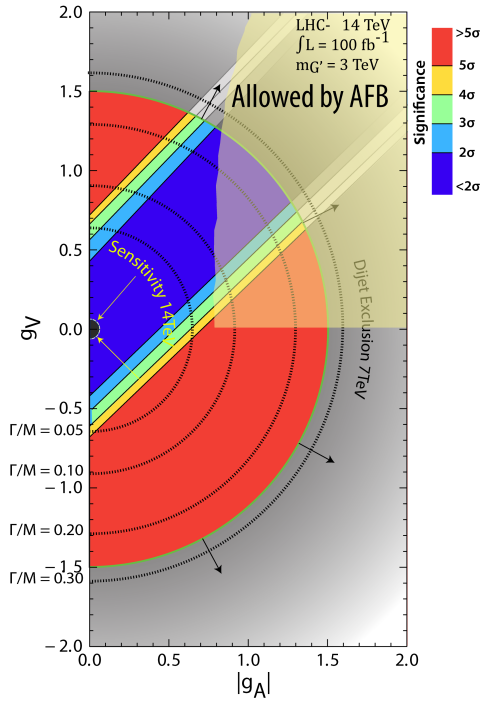


Discovery

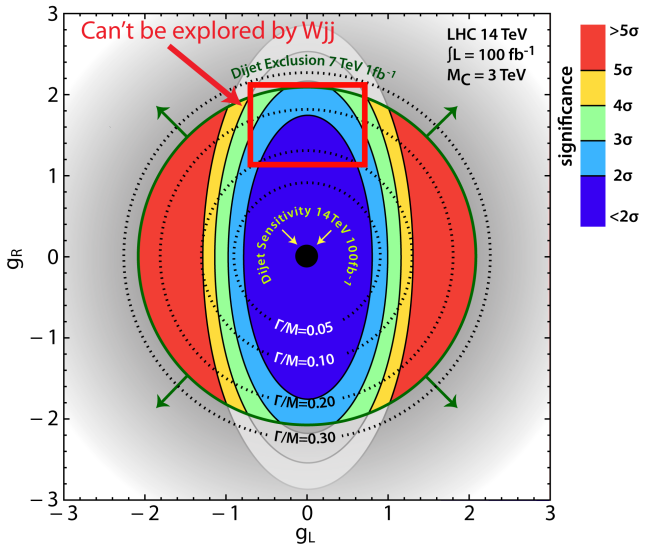


Measurement

- Study LHC 14 TeV, $10\,\mathrm{fb}^{-1}$ and $100\,\mathrm{fb}^{-1}$
- Regions satisfying the dijet constraints and A_{FB} with enough significance for the measurement exist.



- Complementary measurement from Z for region $g_L \simeq 0$



Thank You Very Much!