Some backgrounds (motivation) to pick-up the papers

-- A little exploration to get a hint for new idea to BESIII data analysis (not only these paper)

-- (my point of view) Graviton/Gravitino search has advantage of

-- One of hot topic now since the GW is detected recently

-- Since no new particle is found recently, DM papers assuming the candidate of Gravitino/Graviton is increasing (I feel but no sure !)

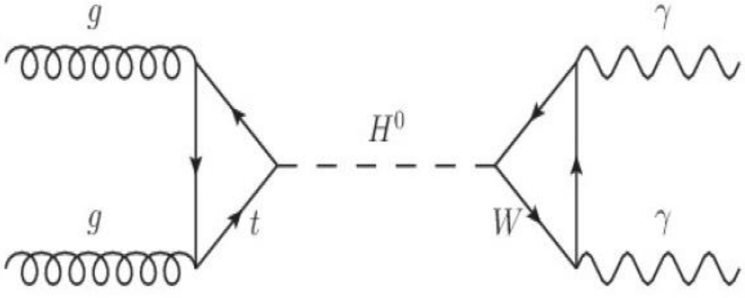
-- Graviton/Gravitino can couple with photons that makes the search "relatively" clean as mentioned in the paper and that is common advantage for colliders.

Search for new phenomena in high-mass diphoton final states using 37 fb^{-1} of proton-proton collisions collected at sqrt(s) = 13 TeV with the ATLAS detector

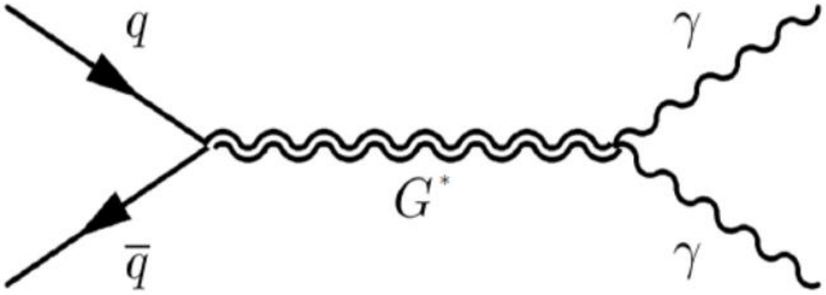
ATLAS Collaboration, Physics Letters B 775 (2017) 105-125

Model

- Heavy Higgs of spin-0 -- extended Higgs sector

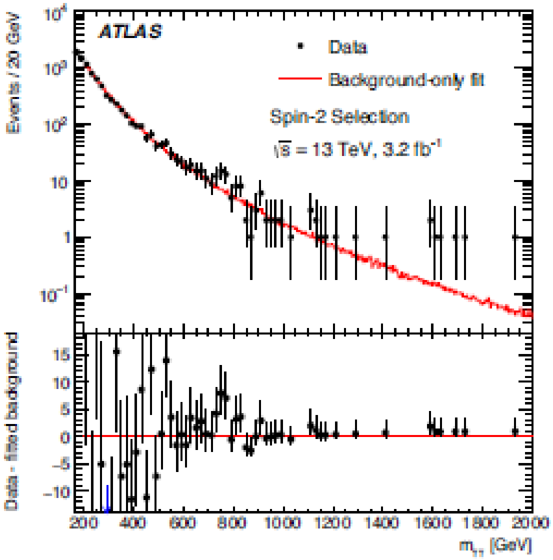


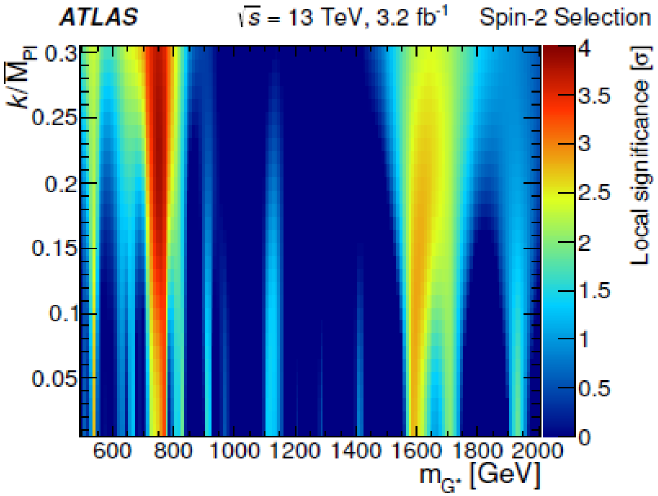
- Randall and Sundrum (RS) model -- exchange of spin-2 particle



- ATLAS (CMS) reported a bump structure around 750 GeV from this diphoton search in 2016.

- ATLAS (CMS) reported a bump structure around 750 GeV



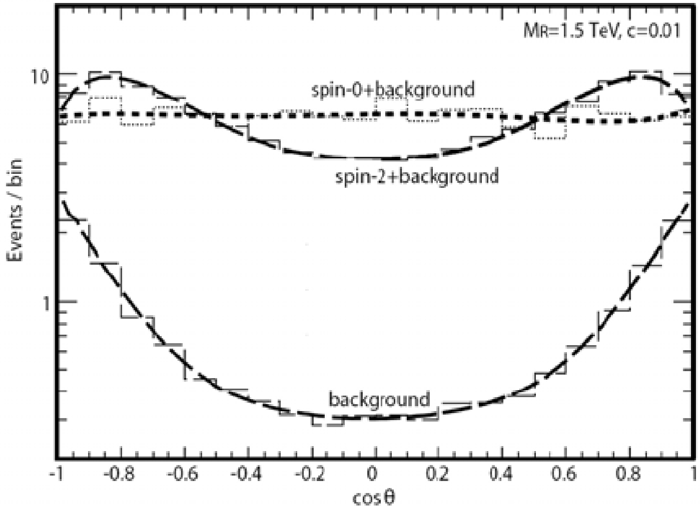


JHEP09 (2016)001

- How we can distinguish the spin ?

. . . seems to be distinguishable
if we can detect with enough statistics

From “Spin-identification of Randall-Sundrum Graviton resonances ... “ A. A. Pankov, A.V.Tsytrinov, and I. A. Serenkova



Event Selection

Data Set : total 36.7 fb^{-1} of pp collision, sqrt(s)=13 TeV , 2015/2016

Event Reconstruction (mainly described for photons):

-- Two photons of highest energies which record more than 40 GeV / 30 GeV is retained.

-- "Tight" photon

-- Isolation from tracks

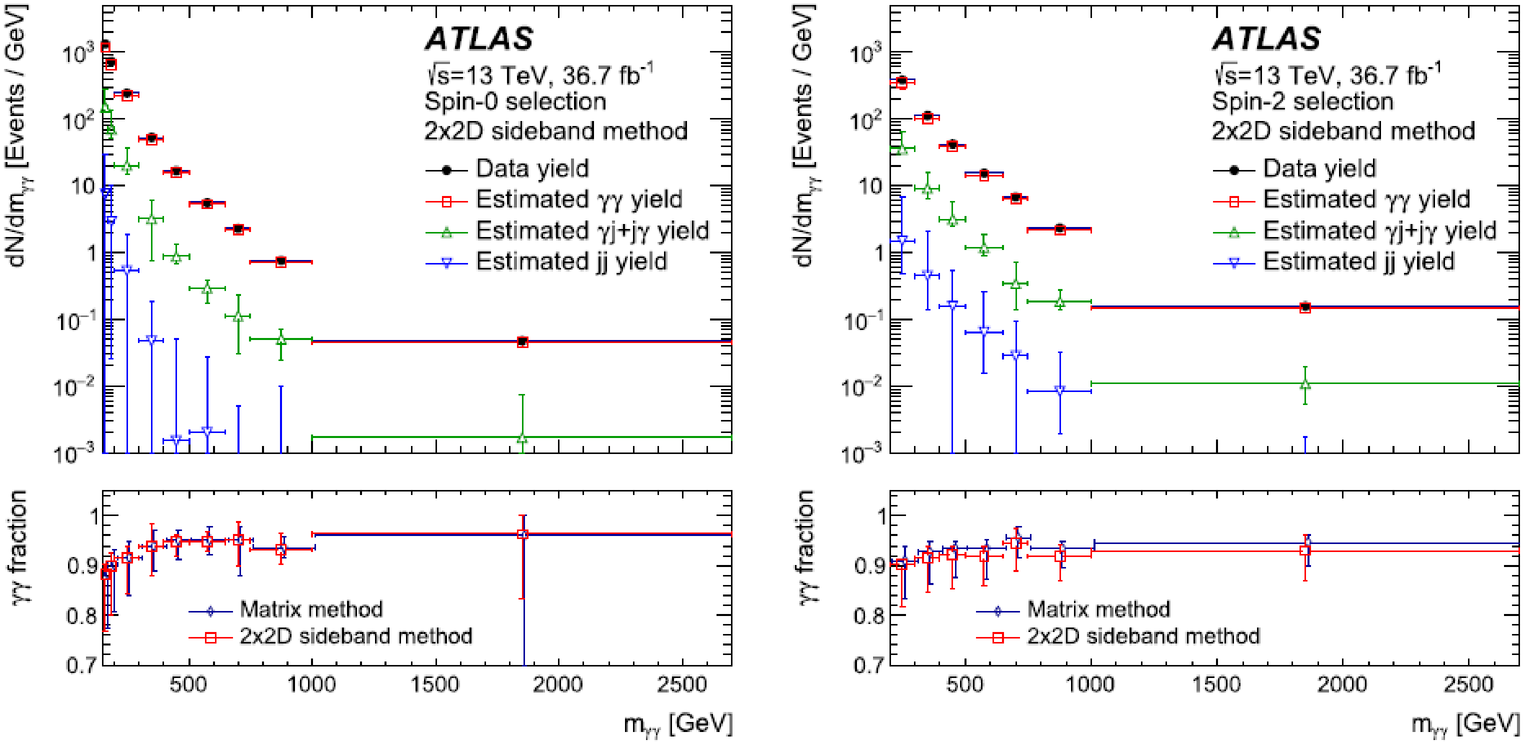
Event Selection :

-- For search of spin-0 signals, the transverse energy $E_T > 0.4m_{\gamma\gamma}$ for the leading photon, and $E_T>0.3m_{\gamma\gamma}$ for the second photon, where $m_{\gamma\gamma}$ denotes diphoton invariant mass

-- For search of spin-2 resonant and non-resonant signals, E_T > 55 GeV (for each photon)

Diphoton invariant mass distribution

-- Estimation of background components is compared with several methods. --

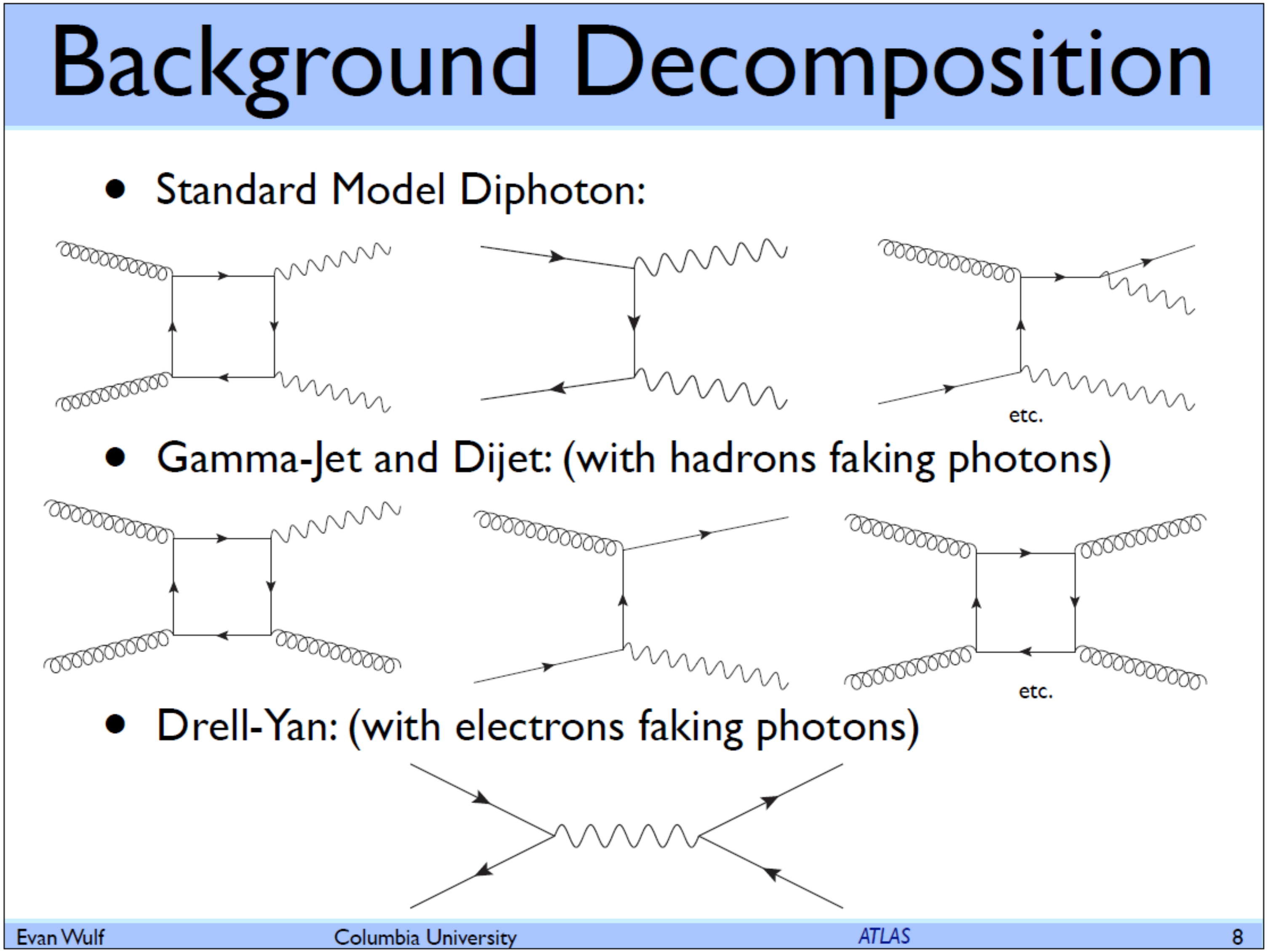


(a) (b)

Fig. 1. The diphoton invariant-mass distributions of the data are shown in the upper panels for (a) the spin-0 and (b) the spin-2 selections and their decomposition into contributions from genuine diphoton ($\gamma\gamma$), photon+jet (γj and $j\gamma$) and dijet (jj) events as determined using the 2×2D sideband method. The bottom panels show the purity of diphoton events as determined by the matrix method and the 2×2D sideband method. Each point in the distributions is plotted in the centre of the corresponding bin. The total uncertainties, including statistical and systematic components added in quadrature, are shown as error bars.

paper claimed that estimation of background component from 3 different methods is consistent each other.

Reference : Background channel to the di-photon events



Background Decomposition

- Standard Model Diphoton:

etc.

- Gamma-Jet and Dijet: (with hadrons faking photons)

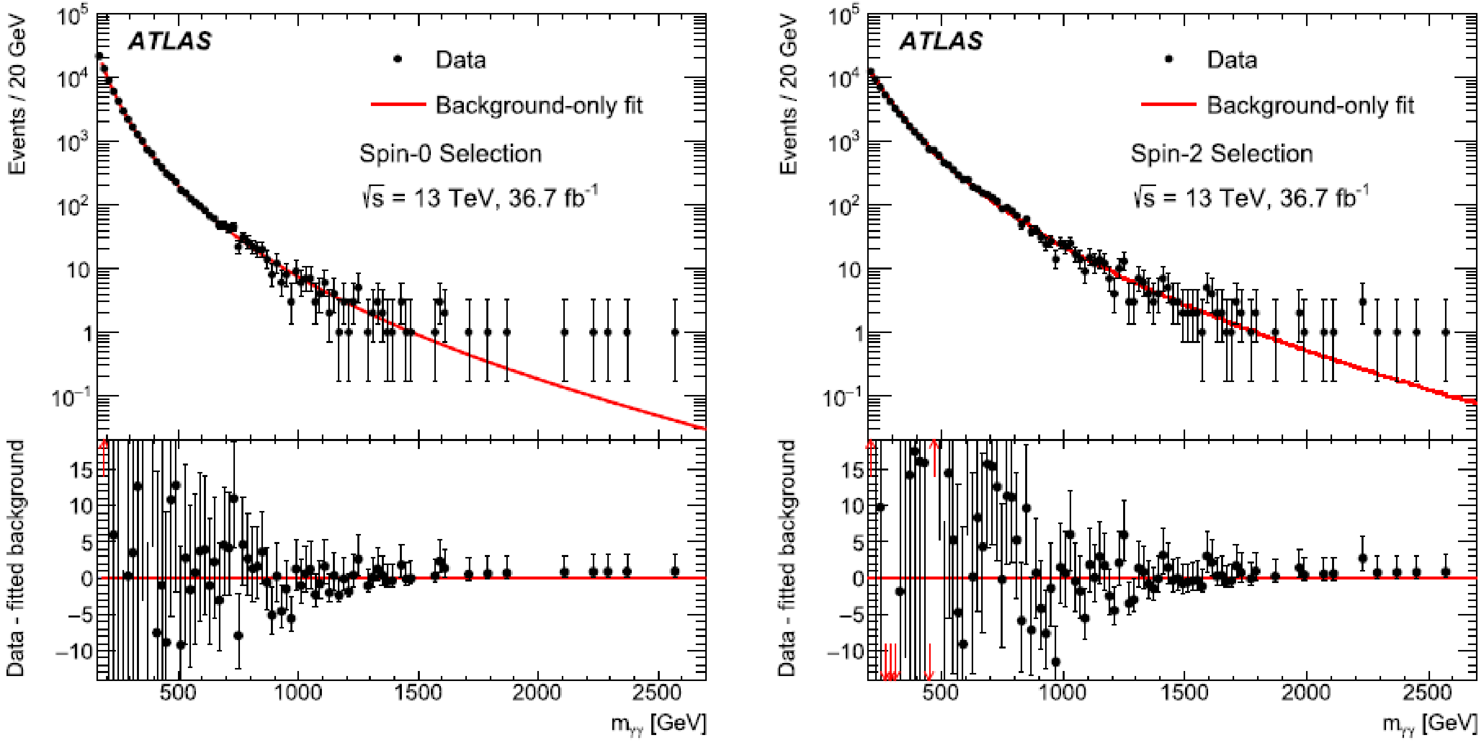
etc.

- Drell-Yan: (with electrons faking photons)

Evan Wulf Columbia University *ATLAS* 8

From “Search for Randall-Sundrum Gravitons at the LHC” , Evan Wulf

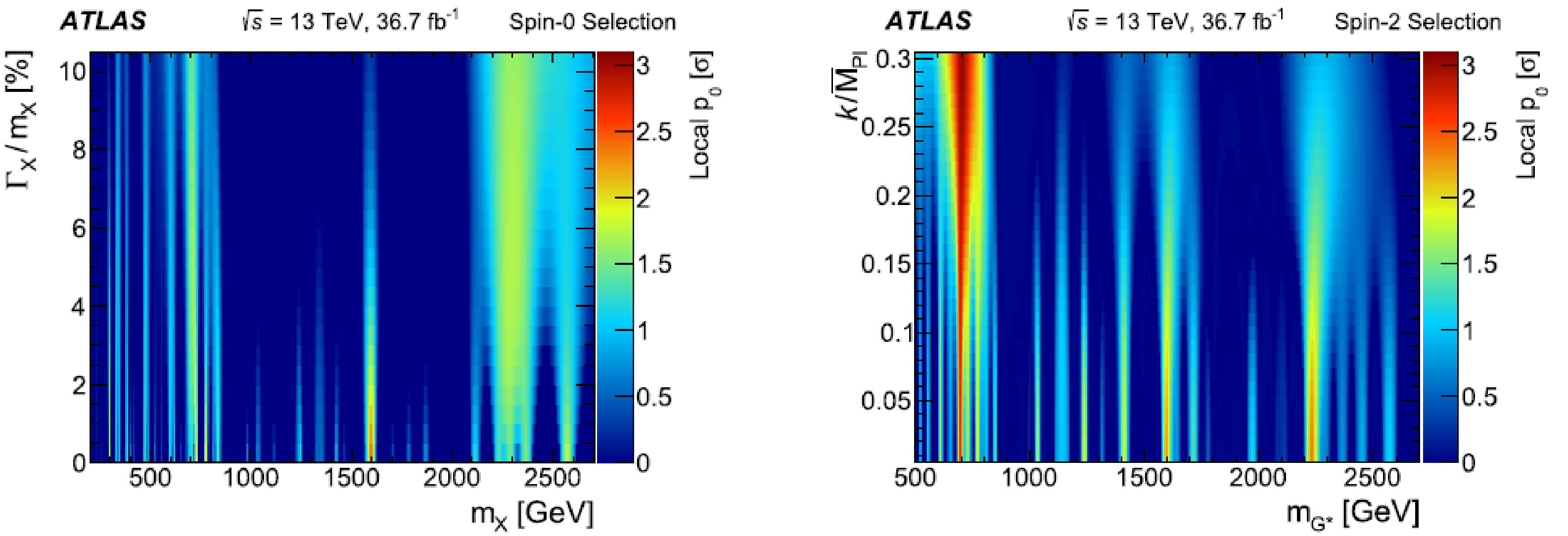
Diphoton invariant mass distribution



(a) (b)

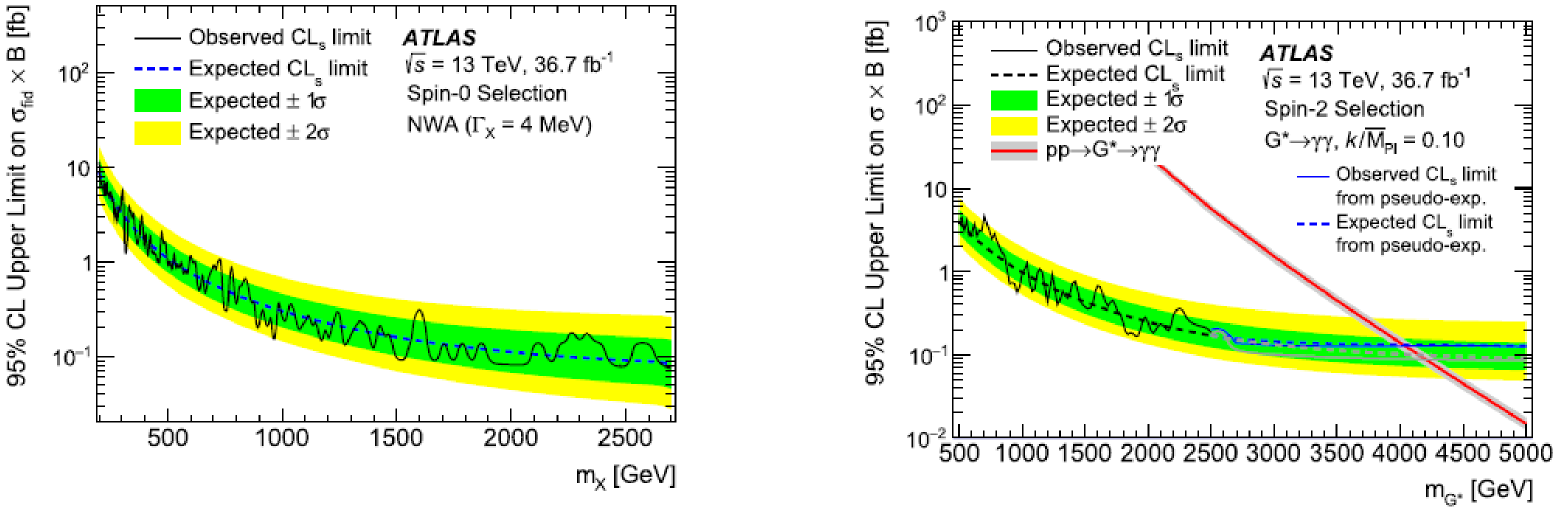
Fig. 2. Distributions of the diphoton invariant mass for events passing (a) the spin-0 selection or (b) the spin-2 selection, with the background-only fits superimposed. The data points are plotted at the centre of each bin. The error bars indicate statistical uncertainties. The differences between the data and the fits are shown in the bottom panels. The arrows in the lower panels indicate values outside the range by more than one standard deviation. There is no data event with $m_{\gamma\gamma} > 2700$ GeV.

Significance and C.L. upper limit



(a)

(b)



(a)

(b)

Short summary of this paper

-- The data are consistent with the SM background expectation and no excess is observed around 750 GeV .

-- In the combined dataset (2015+2016), the largest local deviation for spin-0 (spin-2) resonance search is 2.6σ (3.0σ) , and global significance of this excess is null (0.8σ) for each.

-- RS1 model with $\kappa/M_{PL} = 0.1$ is excluded below m_G=4.1 TeV.

Search for supersymmetry in a final state containing two photons and missing transverse momentum in sqrt(s)=13 TeV pp collisions at the LHC using the ATLAS detector

ATLAS Collaboration, Euro Phys. J. C (2016) 517

Model

- Model of Gauge-mediated supersymmetry breaking (GGM)

- Lightest supersymmetric particle (LSP) is the gravitino $\tilde{\mathrm{G}}$ with a mass of significantly less than 1 GeV.

- Final states consists of di-photon + missing transverse momentum (its magnitude is E_T^{miss})

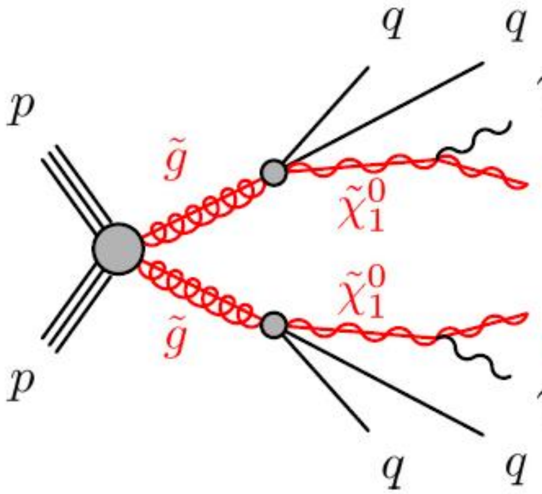


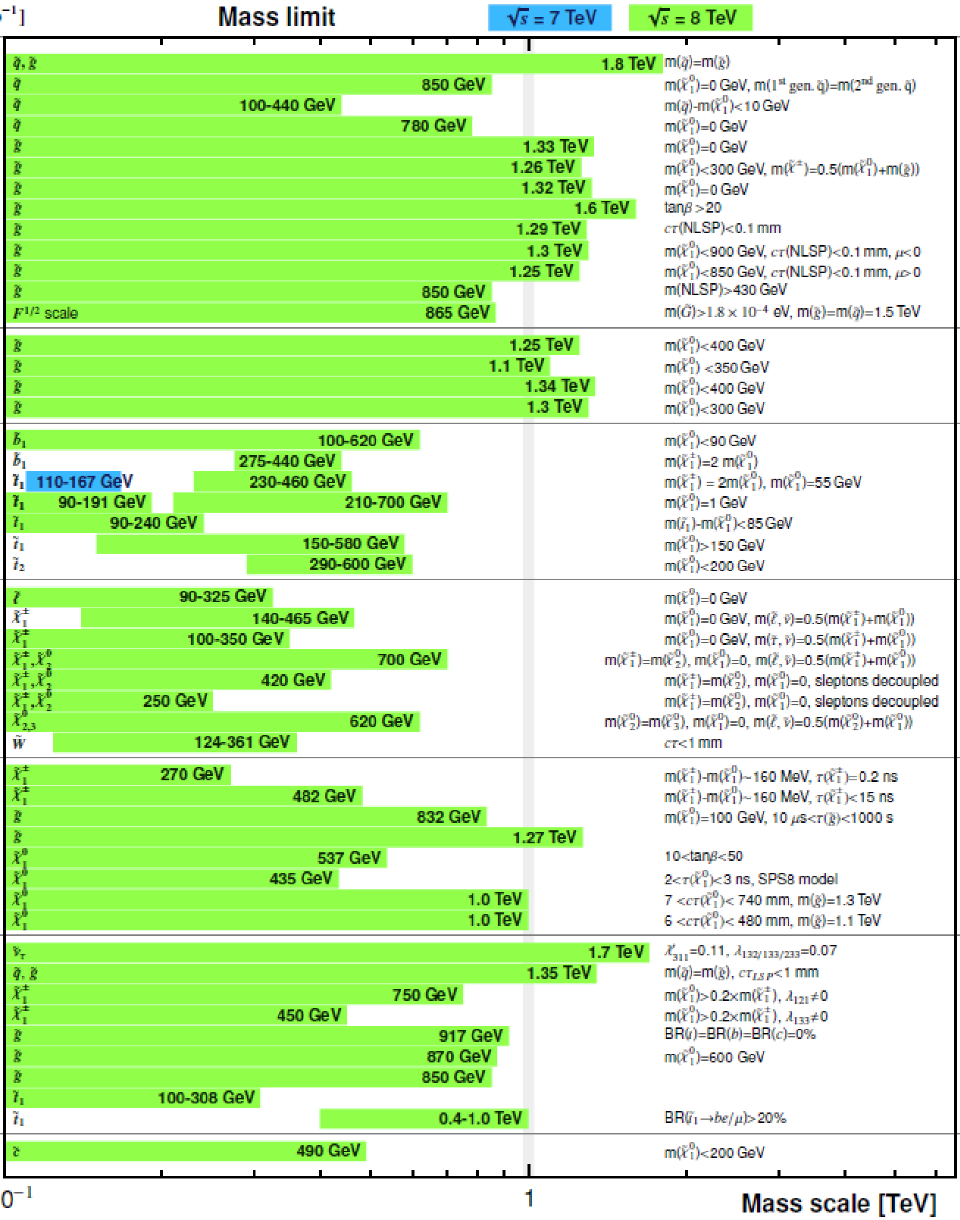
Fig. 1 Typical production and decay-chain processes for the gluino-pair production GGM model for which the NLSP is a bino-like neutralino

ATLAS SUSY Searches* - 95% CL Lower Limits

Status: July 2015

ATLAS Preliminary

$\sqrt{s}$ = 7, 8 TeV



	Model	e,μ,τ,γ	Jets	E_T^{miss}	$\int\mathcal{L}\,dt[\mathrm{fb}^{-1}]$	Mass limit			Reference
Inclusive Searches	MSUGRA/CMSSM	0-3 e,μ/1-2 τ	2-10 jets/3 b	Yes	20.3	$\tilde{q},\tilde{g}$	1.8 TeV	$m(\tilde{q})=m(\tilde{g})$	1507.05525
	$\tilde{q}\tilde{q}$, $\tilde{q}\to q\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{q}$	850 GeV	$m(\tilde{\chi}_1^0)$=0 GeV, m(1st gen. $\tilde{q}$)=m(2nd gen. $\tilde{q}$)	1405.7875
	$\tilde{q}\tilde{q}$, $\tilde{q}\to q\tilde{\chi}_1^0$ (compressed)	mono-jet	1-3 jets	Yes	20.3	$\tilde{q}$	100-440 GeV	$m(\tilde{q})$-$m(\tilde{\chi}_1^0)$<10 GeV	1507.05525
	$\tilde{q}\tilde{q}$, $\tilde{q}\to q(\ell\ell/\ell\nu/\nu\nu)\tilde{\chi}_1^0$	2 e,μ (off-Z)	2 jets	Yes	20.3	$\tilde{q}$	780 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	1503.03290
	$\tilde{g}\tilde{g}$, $\tilde{g}\to q\bar{q}\tilde{\chi}_1^0$	0	2-6 jets	Yes	20.3	$\tilde{g}$	1.33 TeV	$m(\tilde{\chi}_1^0)$=0 GeV	1405.7875
	$\tilde{g}\tilde{g}$, $\tilde{g}\to qq\tilde{\chi}_1^{\pm}\to qqW^{\pm}\tilde{\chi}_1^0$	0-1 e,μ	2-6 jets	Yes	20	$\tilde{g}$	1.26 TeV	$m(\tilde{\chi}_1^0)$<300 GeV, $m(\tilde{\chi}^{\pm})$=0.5($m(\tilde{\chi}_1^0)$+$m(\tilde{g})$)	1507.05525
	$\tilde{g}\tilde{g}$, $\tilde{g}\to qq(\ell\ell/\ell\nu/\nu\nu)\tilde{\chi}_1^0$	2 e,μ	0-3 jets	-	20	$\tilde{g}$	1.32 TeV	$m(\tilde{\chi}_1^0)$=0 GeV	1501.03555
	GMSB ($\tilde{\ell}$ NLSP)	1-2 τ + 0-1 ℓ	0-2 jets	Yes	20.3	$\tilde{g}$	1.6 TeV	$\tan\beta$ >20	1407.0603
	GGM (bino NLSP)	2 γ	-	Yes	20.3	$\tilde{g}$	1.29 TeV	$c\tau$(NLSP)<0.1 mm	1507.05493
	GGM (higgsino-bino NLSP)	γ	1 b	Yes	20.3	$\tilde{g}$	1.3 TeV	$m(\tilde{\chi}_1^0)$<900 GeV, $c\tau$(NLSP)<0.1 mm, μ<0	1507.05493
	GGM (higgsino-bino NLSP)	γ	2 jets	Yes	20.3	$\tilde{g}$	1.25 TeV	$m(\tilde{\chi}_1^0)$<850 GeV, $c\tau$(NLSP)<0.1 mm, μ>0	1507.05493
	GGM (higgsino NLSP)	2 e,μ (Z)	2 jets	Yes	20.3	$\tilde{g}$	850 GeV	m(NLSP)>430 GeV	1503.03290
	Gravitino LSP	0	mono-jet	Yes	20.3	$F^{1/2}$ scale	865 GeV	$m(\tilde{G})>1.8\times10^{-4}$ eV, $m(\tilde{g})=m(\tilde{q})$=1.5 TeV	1502.01518
3rd gen. $\tilde{g}$ med.	$\tilde{g}\tilde{g}$, $\tilde{g}\to b\bar{b}\tilde{\chi}_1^0$	0	3 b	Yes	20.1	$\tilde{g}$	1.25 TeV	$m(\tilde{\chi}_1^0)$<400 GeV	1407.0600
	$\tilde{g}\tilde{g}$, $\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0	7-10 jets	Yes	20.3	$\tilde{g}$	1.1 TeV	$m(\tilde{\chi}_1^0)$ <350 GeV	1308.1841
	$\tilde{g}\tilde{g}$, $\tilde{g}\to t\bar{t}\tilde{\chi}_1^0$	0-1 e,μ	3 b	Yes	20.1	$\tilde{g}$	1.34 TeV	$m(\tilde{\chi}_1^0)$<400 GeV	1407.0600
	$\tilde{g}\tilde{g}$, $\tilde{g}\to b\bar{t}\tilde{\chi}_1^+$	0-1 e,μ	3 b	Yes	20.1	$\tilde{g}$	1.3 TeV	$m(\tilde{\chi}_1^0)$<300 GeV	1407.0600
3rd gen. squarks direct production	$\tilde{b}_1\tilde{b}_1$, $\tilde{b}_1\to b\tilde{\chi}_1^0$	0	2 b	Yes	20.1	$\tilde{b}_1$	100-620 GeV	$m(\tilde{\chi}_1^0)$<90 GeV	1308.2631
	$\tilde{b}_1\tilde{b}_1$, $\tilde{b}_1\to t\tilde{\chi}_1^{\pm}$	2 e,μ (SS)	0-3 b	Yes	20.3	$\tilde{b}_1$	275-440 GeV	$m(\tilde{\chi}_1^{\pm})$=2 $m(\tilde{\chi}_1^0)$	1404.2500
	$\tilde{t}_1\tilde{t}_1$, $\tilde{t}_1\to b\tilde{\chi}_1^{\pm}$	1-2 e,μ	1-2 b	Yes	4.7/20.3	$\tilde{t}_1$	110-167 GeV 230-460 GeV	$m(\tilde{\chi}_1^{\pm})$ = 2$m(\tilde{\chi}_1^0)$, $m(\tilde{\chi}_1^0)$=55 GeV	1209.2102, 1407.0583
	$\tilde{t}_1\tilde{t}_1$, $\tilde{t}_1\to Wb\tilde{\chi}_1^0$ or $t\tilde{\chi}_1^0$	0-2 e,μ	0-2 jets/1-2 b	Yes	20.3	$\tilde{t}_1$	90-191 GeV 210-700 GeV	$m(\tilde{\chi}_1^0)$=1 GeV	1506.08616
	$\tilde{t}_1\tilde{t}_1$, $\tilde{t}_1\to c\tilde{\chi}_1^0$	0	mono-jet/c-tag	Yes	20.3	$\tilde{t}_1$	90-240 GeV	$m(\tilde{t}_1)$-$m(\tilde{\chi}_1^0)$<85 GeV	1407.0608
	$\tilde{t}_1\tilde{t}_1$ (natural GMSB)	2 e,μ (Z)	1 b	Yes	20.3	$\tilde{t}_1$	150-580 GeV	$m(\tilde{\chi}_1^0)$>150 GeV	1403.5222
	$\tilde{t}_2\tilde{t}_2$, $\tilde{t}_2\to\tilde{t}_1$ + Z	3 e,μ (Z)	1 b	Yes	20.3	$\tilde{t}_2$	290-600 GeV	$m(\tilde{\chi}_1^0)$<200 GeV	1403.5222
EW direct	$\tilde{\ell}_{L,R}\tilde{\ell}_{L,R}$, $\tilde{\ell}\to\ell\tilde{\chi}_1^0$	2 e,μ	0	Yes	20.3	$\tilde{\ell}$	90-325 GeV	$m(\tilde{\chi}_1^0)$=0 GeV	1403.5294
	$\tilde{\chi}_1^+\tilde{\chi}_1^-$, $\tilde{\chi}_1^+\to\tilde{\ell}\nu(\ell\tilde{\nu})$	2 e,μ	0	Yes	20.3	$\tilde{\chi}_1^{\pm}$	140-465 GeV	$m(\tilde{\chi}_1^0)$=0 GeV, $m(\tilde{\ell},\tilde{\nu})$=0.5($m(\tilde{\chi}_1^{\pm})$+$m(\tilde{\chi}_1^0)$)	1403.5294
	$\tilde{\chi}_1^+\tilde{\chi}_1^-$, $\tilde{\chi}_1^+\to\tilde{\tau}\nu(\tau\tilde{\nu})$	2 τ	-	Yes	20.3	$\tilde{\chi}_1^{\pm}$	100-350 GeV	$m(\tilde{\chi}_1^0)$=0 GeV, $m(\tilde{\tau},\tilde{\nu})$=0.5($m(\tilde{\chi}_1^{\pm})$+$m(\tilde{\chi}_1^0)$)	1407.0350
	$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0\to\tilde{\ell}_L\nu\tilde{\ell}_L\ell(\tilde{\nu}\nu)$, $\ell\tilde{\nu}\tilde{\ell}_L\ell(\tilde{\nu}\nu)$	3 e,μ	0	Yes	20.3	$\tilde{\chi}_1^{\pm},\tilde{\chi}_2^0$	700 GeV	$m(\tilde{\chi}_1^{\pm})$=$m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0)$=0, $m(\tilde{\ell},\tilde{\nu})$=0.5($m(\tilde{\chi}_1^{\pm})$+$m(\tilde{\chi}_1^0)$)	1402.7029
	$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0\to W\tilde{\chi}_1^0Z\tilde{\chi}_1^0$	2-3 e,μ	0-2 jets	Yes	20.3	$\tilde{\chi}_1^{\pm},\tilde{\chi}_2^0$	420 GeV	$m(\tilde{\chi}_1^{\pm})$=$m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0)$=0, sleptons decoupled	1403.5294, 1402.7029
	$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0\to W\tilde{\chi}_1^0h\tilde{\chi}_1^0$, $h\to b\bar{b}/WW/\tau\tau/\gamma\gamma$	e,μ,γ	0-2 b	Yes	20.3	$\tilde{\chi}_1^{\pm},\tilde{\chi}_2^0$	250 GeV	$m(\tilde{\chi}_1^{\pm})$=$m(\tilde{\chi}_2^0)$, $m(\tilde{\chi}_1^0)$=0, sleptons decoupled	1501.07110
	$\tilde{\chi}_2^0\tilde{\chi}_3^0$, $\tilde{\chi}_{2,3}^0\to\tilde{\ell}_R\ell$	4 e,μ	0	Yes	20.3	$\tilde{\chi}_{2,3}^0$	620 GeV	$m(\tilde{\chi}_2^0)$=$m(\tilde{\chi}_3^0)$, $m(\tilde{\chi}_1^0)$=0, $m(\tilde{\ell},\tilde{\nu})$=0.5($m(\tilde{\chi}_2^0)$+$m(\tilde{\chi}_1^0)$)	1405.5086
	GGM (wino NLSP) weak prod.	1 e,μ + γ	-	Yes	20.3	$\tilde{W}$	124-361 GeV	$c\tau$<1 mm	1507.05493
Long-lived particles	Direct $\tilde{\chi}_1^+\tilde{\chi}_1^-$ prod., long-lived $\tilde{\chi}_1^{\pm}$	Disapp. trk	1 jet	Yes	20.3	$\tilde{\chi}_1^{\pm}$	270 GeV	$m(\tilde{\chi}_1^{\pm})$-$m(\tilde{\chi}_1^0)$~160 MeV, $\tau(\tilde{\chi}_1^{\pm})$=0.2 ns	1310.3675
	Direct $\tilde{\chi}_1^+\tilde{\chi}_1^-$ prod., long-lived $\tilde{\chi}_1^{\pm}$	dE/dx trk	-	Yes	18.4	$\tilde{\chi}_1^{\pm}$	482 GeV	$m(\tilde{\chi}_1^{\pm})$-$m(\tilde{\chi}_1^0)$~160 MeV, $\tau(\tilde{\chi}_1^{\pm})$<15 ns	1506.05332
	Stable, stopped $\tilde{g}$ R-hadron	0	1-5 jets	Yes	27.9	$\tilde{g}$	832 GeV	$m(\tilde{\chi}_1^0)$=100 GeV, 10 μs<$\tau(\tilde{g})$<1000 s	1310.6584
	Stable $\tilde{g}$ R-hadron	trk	-	-	19.1	$\tilde{g}$	1.27 TeV		1411.6795
	GMSB, stable $\tilde{\tau}$, $\tilde{\chi}_1^0\to\tilde{\tau}(\tilde{e},\tilde{\mu})+\tau(e,\mu)$	1-2 μ	-	-	19.1	$\tilde{\chi}_1^0$	537 GeV	10<$\tan\beta$<50	1411.6795
	GMSB, $\tilde{\chi}_1^0\to\gamma\tilde{G}$, long-lived $\tilde{\chi}_1^0$	2 γ	-	Yes	20.3	$\tilde{\chi}_1^0$	435 GeV	2<$\tau(\tilde{\chi}_1^0)$<3 ns, SPS8 model	1409.5542
	$\tilde{g}\tilde{g}$, $\tilde{\chi}_1^0\to ee\nu/e\mu\nu/\mu\mu\nu$	displ. $ee/e\mu/\mu\mu$	-	-	20.3	$\tilde{\chi}_1^0$	1.0 TeV	7 <$c\tau(\tilde{\chi}_1^0)$< 740 mm, $m(\tilde{g})$=1.3 TeV	1504.05162
	GGM $\tilde{g}\tilde{g}$, $\tilde{\chi}_1^0\to Z\tilde{G}$	displ. vtx + jets	-	-	20.3	$\tilde{\chi}_1^0$	1.0 TeV	6 <$c\tau(\tilde{\chi}_1^0)$< 480 mm, $m(\tilde{g})$=1.1 TeV	1504.05162
RPV	LFV $pp\to\tilde{\nu}_\tau+X$, $\tilde{\nu}_\tau\to e\mu/e\tau/\mu\tau$	$e\mu$,$e\tau$,$\mu\tau$	-	-	20.3	$\tilde{\nu}_\tau$	1.7 TeV	λ'_{311}=0.11, $\lambda_{132/133/233}$=0.07	1503.04430
	Bilinear RPV CMSSM	2 e,μ (SS)	0-3 b	Yes	20.3	$\tilde{q},\tilde{g}$	1.35 TeV	$m(\tilde{q})=m(\tilde{g})$, $c\tau_{LSP}$<1 mm	1404.2500
	$\tilde{\chi}_1^+\tilde{\chi}_1^-$, $\tilde{\chi}_1^+\to W\tilde{\chi}_1^0$, $\tilde{\chi}_1^0\to ee\tilde{\nu}_\mu$, $e\mu\tilde{\nu}_e$	4 e,μ	-	Yes	20.3	$\tilde{\chi}_1^{\pm}$	750 GeV	$m(\tilde{\chi}_1^0)$>0.2×$m(\tilde{\chi}_1^{\pm})$, $\lambda_{121}\neq0$	1405.5086
	$\tilde{\chi}_1^+\tilde{\chi}_1^-$, $\tilde{\chi}_1^+\to W\tilde{\chi}_1^0$, $\tilde{\chi}_1^0\to\tau\tau\tilde{\nu}_e$, $e\tau\tilde{\nu}_\tau$	3 e,μ + τ	-	Yes	20.3	$\tilde{\chi}_1^{\pm}$	450 GeV	$m(\tilde{\chi}_1^0)$>0.2×$m(\tilde{\chi}_1^{\pm})$, $\lambda_{133}\neq0$	1405.5086
	$\tilde{g}\tilde{g}$, $\tilde{g}\to qqq$	0	6-7 jets	-	20.3	$\tilde{g}$	917 GeV	BR(t)=BR(b)=BR(c)=0%	1502.05686
	$\tilde{g}\tilde{g}$, $\tilde{g}\to q\tilde{\chi}_1^0$, $\tilde{\chi}_1^0\to qqq$	0	6-7 jets	-	20.3	$\tilde{g}$	870 GeV	$m(\tilde{\chi}_1^0)$=600 GeV	1502.05686
	$\tilde{g}\tilde{g}$, $\tilde{g}\to\tilde{t}_1t$, $\tilde{t}_1\to bs$	2 e,μ (SS)	0-3 b	Yes	20.3	$\tilde{g}$	850 GeV		1404.250
	$\tilde{t}_1\tilde{t}_1$, $\tilde{t}_1\to bs$	0	2 jets + 2 b	-	20.3	$\tilde{t}_1$	100-308 GeV		ATLAS-CONF-2015-026
	$\tilde{t}_1\tilde{t}_1$, $\tilde{t}_1\to b\ell$	2 e,μ	2 b	-	20.3	$\tilde{t}_1$	0.4-1.0 TeV	BR($\tilde{t}_1\to be/\mu$)>20%	ATLAS-CONF-2015-015
Other	Scalar charm, $\tilde{c}\to c\tilde{\chi}_1^0$	0	2 c	Yes	20.3	$\tilde{c}$	490 GeV	$m(\tilde{\chi}_1^0)$<200 GeV	1501.01325

*Only a selection of the available mass limits on new states or phenomena is shown. All limits quoted are observed minus 1σ theoretical signal cross section uncertainty.

Event Selection

Data Set : 3.2 fb^{-1} of pp collision, sqrt(s)=13 TeV , 2015

Event Reconstruction : electron/muon/jet/photon...

Event Selection : two tight photons with p_T>75 GeV

H_T : scalar sum of the P_T of photons and leptons/jets

meff : $H_T + E_T^{miss}$ == Total E involved in the GGM process

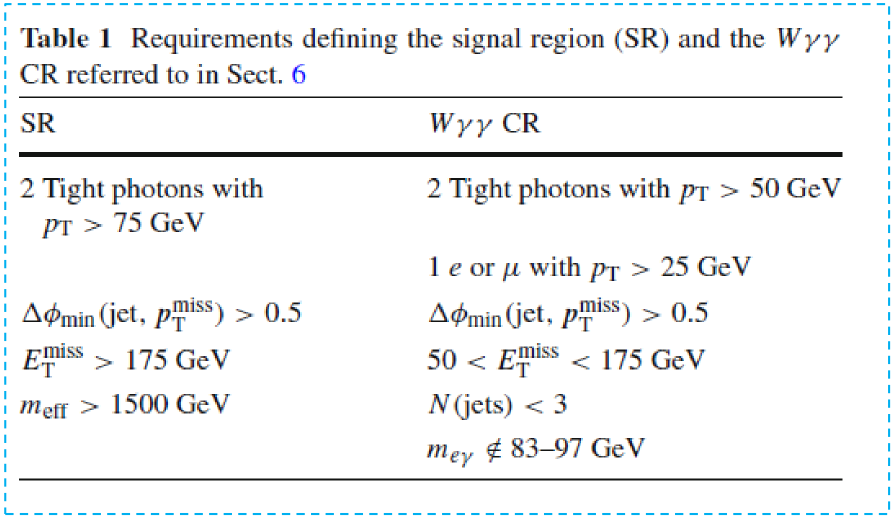
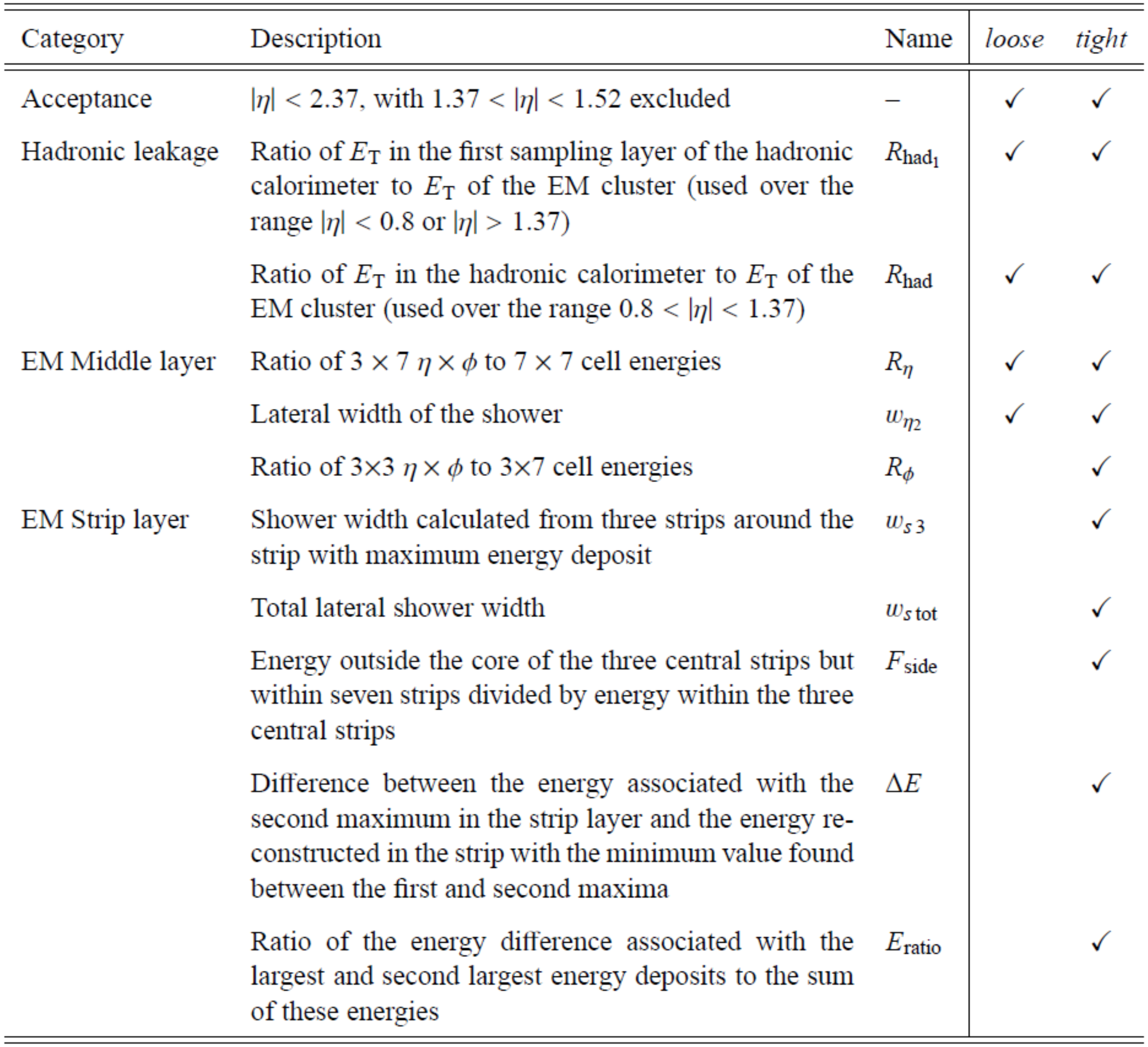


Table 1 Requirements defining the signal region (SR) and the $W\gamma\gamma$ CR referred to in Sect. 6

SR	$W\gamma\gamma$ CR
2 Tight photons with $p_T > 75$ GeV	2 Tight photons with $p_T > 50$ GeV
	1 e or μ with $p_T > 25$ GeV
$\Delta\phi_{\mathrm{min}}(\mathrm{jet}, p_T^{\mathrm{miss}}) > 0.5$	$\Delta\phi_{\mathrm{min}}(\mathrm{jet}, p_T^{\mathrm{miss}}) > 0.5$
$E_T^{\mathrm{miss}} > 175$ GeV	$50 < E_T^{\mathrm{miss}} < 175$ GeV
$m_{\mathrm{eff}} > 1500$ GeV	$N(\mathrm{jets}) < 3$
	$m_{e\gamma} \notin 83$–97 GeV

Reference : “loose” photon and “tight” photon

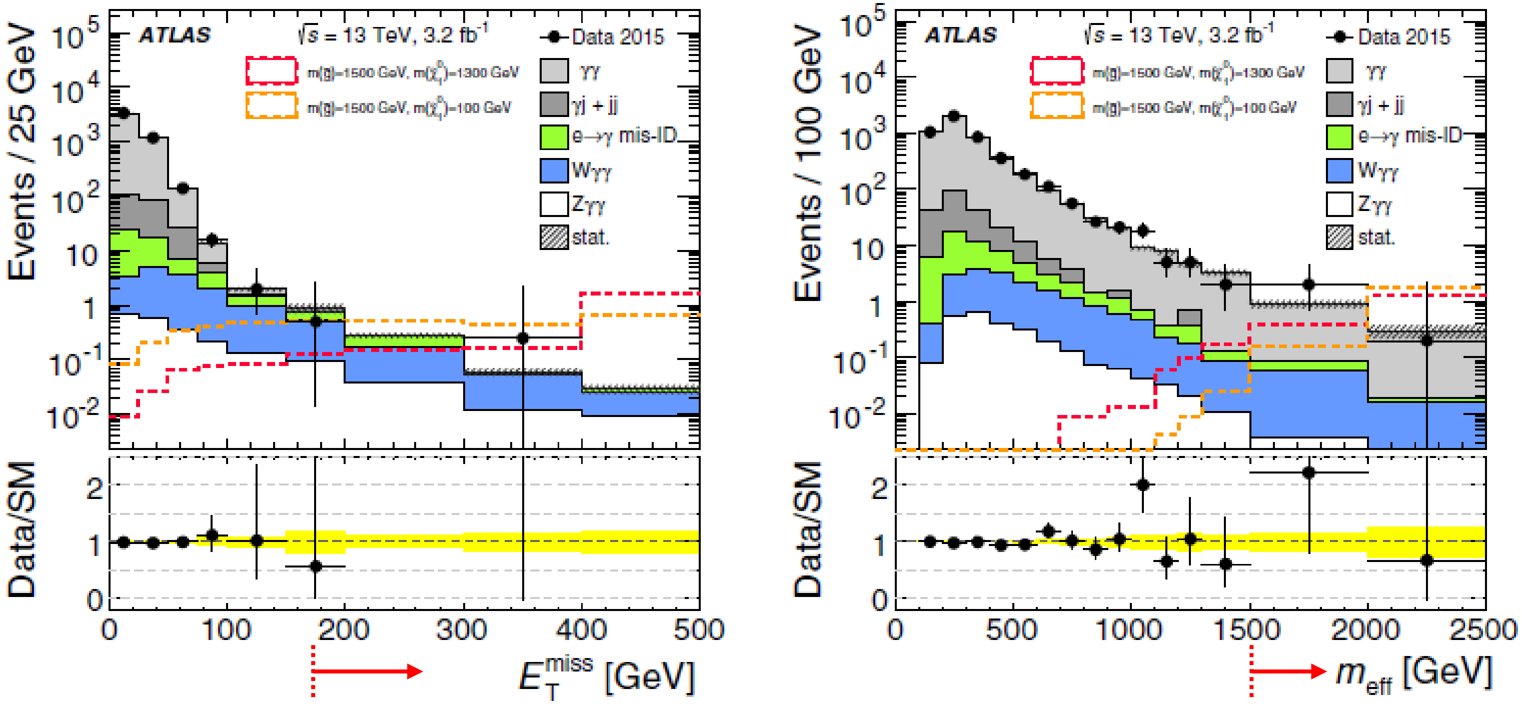


Category	Description	Name	*loose*	*tight*
Acceptance	$\|\eta\| < 2.37$, with $1.37 < \|\eta\| < 1.52$ excluded	–	✓	✓
Hadronic leakage	Ratio of E_T in the first sampling layer of the hadronic calorimeter to E_T of the EM cluster (used over the range $\|\eta\| < 0.8$ or $\|\eta\| > 1.37$)	R_{had_1}	✓	✓
	Ratio of E_T in the hadronic calorimeter to E_T of the EM cluster (used over the range $0.8 < \|\eta\| < 1.37$)	R_{had}	✓	✓
EM Middle layer	Ratio of 3×7 $\eta \times \phi$ to 7×7 cell energies	R_η	✓	✓
	Lateral width of the shower	w_{η_2}	✓	✓
	Ratio of 3×3 $\eta \times \phi$ to 3×7 cell energies	R_ϕ		✓
EM Strip layer	Shower width calculated from three strips around the strip with maximum energy deposit	$w_{s\,3}$		✓
	Total lateral shower width	$w_{s\,\text{tot}}$		✓
	Energy outside the core of the three central strips but within seven strips divided by energy within the three central strips	F_{side}		✓
	Difference between the energy associated with the second maximum in the strip layer and the energy reconstructed in the strip with the minimum value found between the first and second maxima	ΔE		✓
	Ratio of the energy difference associated with the largest and second largest energy deposits to the sum of these energies	E_{ratio}		✓

Table 1: Discriminating variables used for *loose* and *tight* photon identification.

“measurement of the photon identification efficiencies with the ATLAS detector using LHC Run01 data” (2016) arXiv: 1606.01813

E_T^{miss} & m_{eff} distribution of the di-photon sample



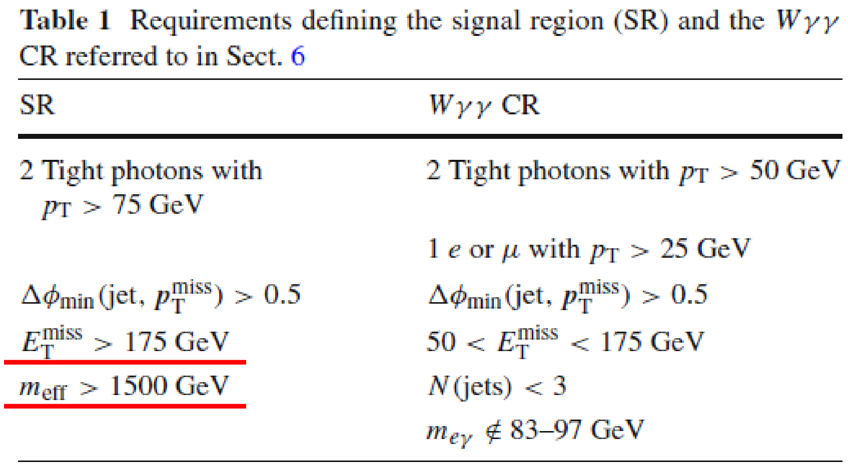


Table 1 Requirements defining the signal region (SR) and the $W\gamma\gamma$ CR referred to in Sect. 6

SR	$W\gamma\gamma$ CR
2 Tight photons with $p_T > 75$ GeV	2 Tight photons with $p_T > 50$ GeV
	1 e or μ with $p_T > 25$ GeV
$\Delta\phi_{min}(\text{jet}, p_T^{miss}) > 0.5$	$\Delta\phi_{min}(\text{jet}, p_T^{miss}) > 0.5$
$E_T^{miss} > 175$ GeV	$50 < E_T^{miss} < 175$ GeV
$m_{eff} > 1500$ GeV	$N(\text{jets}) < 3$
	$m_{e\gamma} \notin 83$–97 GeV

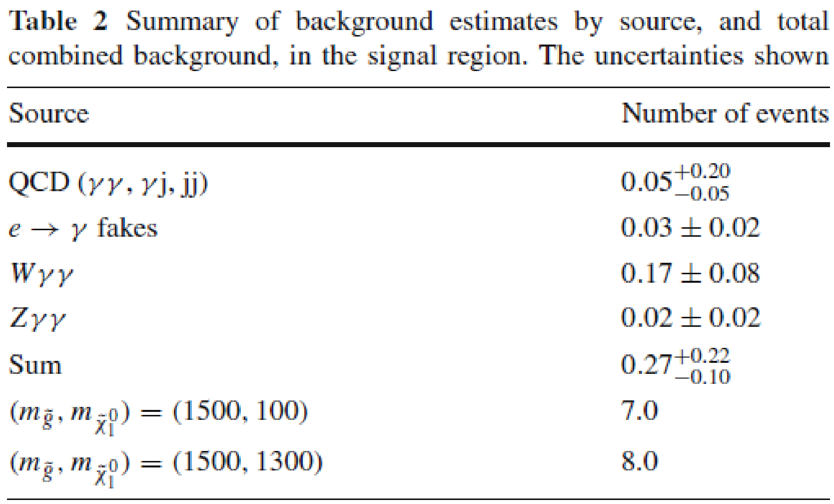


Table 2 Summary of background estimates by source, and total combined background, in the signal region. The uncertainties shown

Source	Number of events
QCD ($\gamma\gamma$, γj, jj)	$0.05^{+0.20}_{-0.05}$
$e \rightarrow \gamma$ fakes	0.03 ± 0.02
$W\gamma\gamma$	0.17 ± 0.08
$Z\gamma\gamma$	0.02 ± 0.02
Sum	$0.27^{+0.22}_{-0.10}$
$(m_{\tilde{g}}, m_{\tilde{\chi}_1^0}) = (1500, 100)$	7.0
$(m_{\tilde{g}}, m_{\tilde{\chi}_1^0}) = (1500, 1300)$	8.0

Results and C.L. upper limit

- After the selection, number of events in the signal region is 0 where as that of expected SM background event is 0.27 .

- By considering uncertainties, 95% C.L. on the non-SM is 3 events.

- 95% C.L. on the cross section 0.93 fb.

with many (widely accepted) assumption on SUSY model , , ,

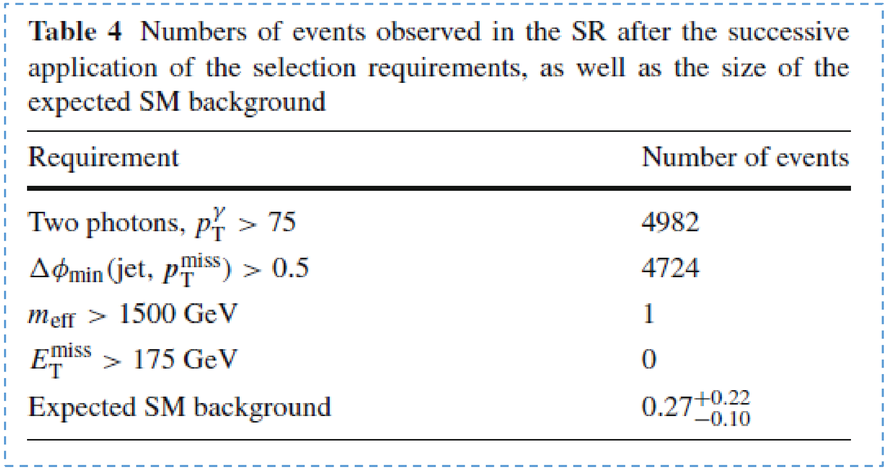
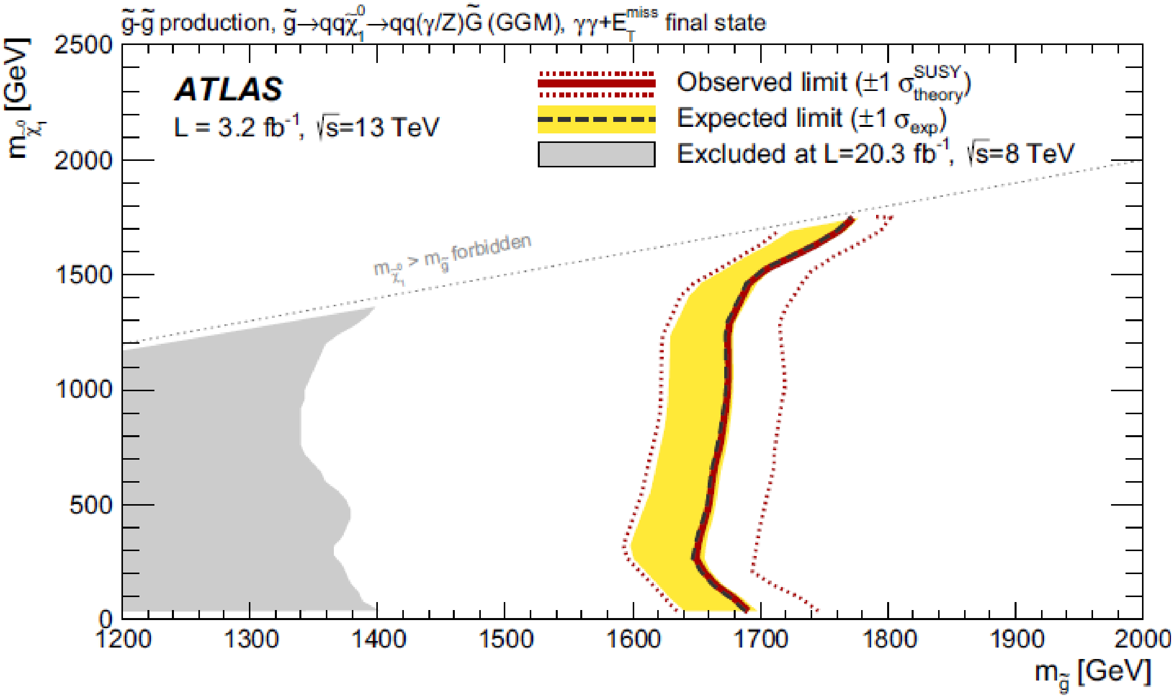


Table 4 Numbers of events observed in the SR after the successive application of the selection requirements, as well as the size of the expected SM background

Requirement	Number of events
Two photons, $p_T^{\gamma} > 75$	4982
$\Delta\phi_{\min}(\text{jet}, p_T^{\text{miss}}) > 0.5$	4724
$m_{\text{eff}} > 1500$ GeV	1
$E_T^{\text{miss}} > 175$ GeV	0
Expected SM background	$0.27^{+0.22}_{-0.10}$



Short summary of this paper

-- No events in the signal region is observed where the SM background is extimated to be 0.27 events.

-- 95% C.L. upper limit of 3.0 events (0.93 fb) on the number of events (cross section) due to the BSM is obtained.

-- In the context of GGM model (with a bino-like NLSP) it leads to a lower limit of 1650 GeV in the gluino mass.

Reference -- ATLAS-CONF-2017-080

-- Update analysis by using total 36.1 fb^{-1} pp collision at sqrt(s)=13 TeV

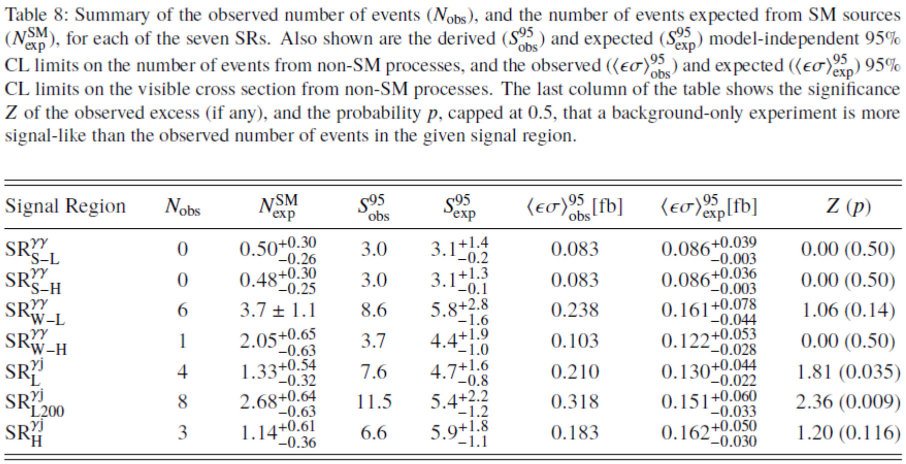
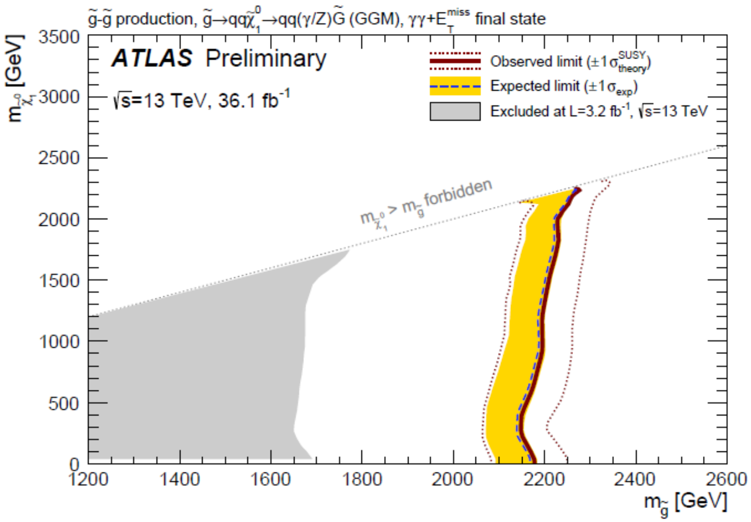


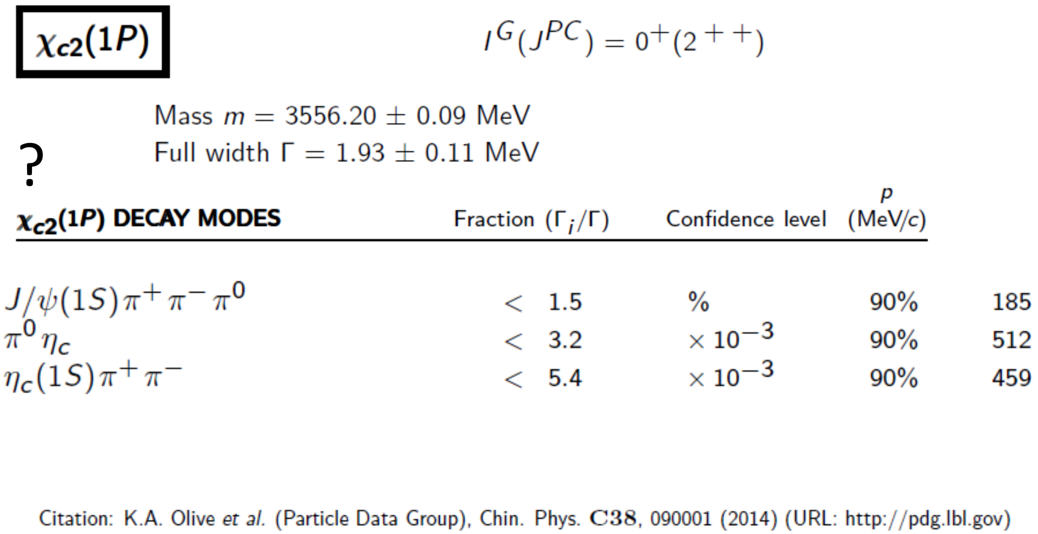
Table 8: Summary of the observed number of events (N_{obs}), and the number of events expected from SM sources ($N^{\mathrm{SM}}_{\mathrm{exp}}$), for each of the seven SRs. Also shown are the derived (S^{95}_{obs}) and expected (S^{95}_{exp}) model-independent 95% CL limits on the number of events from non-SM processes, and the observed ($\langle\epsilon\sigma\rangle^{95}_{\mathrm{obs}}$) and expected ($\langle\epsilon\sigma\rangle^{95}_{\mathrm{exp}}$) 95% CL limits on the visible cross section from non-SM processes. The last column of the table shows the significance Z of the observed excess (if any), and the probability p, capped at 0.5, that a background-only experiment is more signal-like than the observed number of events in the given signal region.

Signal Region	N_{obs}	$N^{\mathrm{SM}}_{\mathrm{exp}}$	S^{95}_{obs}	S^{95}_{exp}	$\langle\epsilon\sigma\rangle^{95}_{\mathrm{obs}}$[fb]	$\langle\epsilon\sigma\rangle^{95}_{\mathrm{exp}}$[fb]	Z (p)
$\mathrm{SR}^{\gamma\gamma}_{\mathrm{S-L}}$	0	$0.50^{+0.30}_{-0.26}$	3.0	$3.1^{+1.4}_{-0.2}$	0.083	$0.086^{+0.039}_{-0.003}$	0.00 (0.50)
$\mathrm{SR}^{\gamma\gamma}_{\mathrm{S-H}}$	0	$0.48^{+0.30}_{-0.25}$	3.0	$3.1^{+1.3}_{-0.1}$	0.083	$0.086^{+0.036}_{-0.003}$	0.00 (0.50)
$\mathrm{SR}^{\gamma\gamma}_{\mathrm{W-L}}$	6	3.7 ± 1.1	8.6	$5.8^{+2.8}_{-1.6}$	0.238	$0.161^{+0.078}_{-0.044}$	1.06 (0.14)
$\mathrm{SR}^{\gamma\gamma}_{\mathrm{W-H}}$	1	$2.05^{+0.65}_{-0.63}$	3.7	$4.4^{+1.9}_{-1.0}$	0.103	$0.122^{+0.053}_{-0.028}$	0.00 (0.50)
$\mathrm{SR}^{\gamma j}_{\mathrm{L}}$	4	$1.33^{+0.54}_{-0.32}$	7.6	$4.7^{+1.6}_{-0.8}$	0.210	$0.130^{+0.044}_{-0.022}$	1.81 (0.035)
$\mathrm{SR}^{\gamma j}_{\mathrm{L200}}$	8	$2.68^{+0.64}_{-0.63}$	11.5	$5.4^{+2.2}_{-1.2}$	0.318	$0.151^{+0.060}_{-0.033}$	2.36 (0.009)
$\mathrm{SR}^{\gamma j}_{\mathrm{H}}$	3	$1.14^{+0.61}_{-0.36}$	6.6	$5.9^{+1.8}_{-1.1}$	0.183	$0.162^{+0.050}_{-0.030}$	1.20 (0.116)



For BESIII --- Example

Chic2->etac(1S) + G(->$\gamma\gamma$) ?

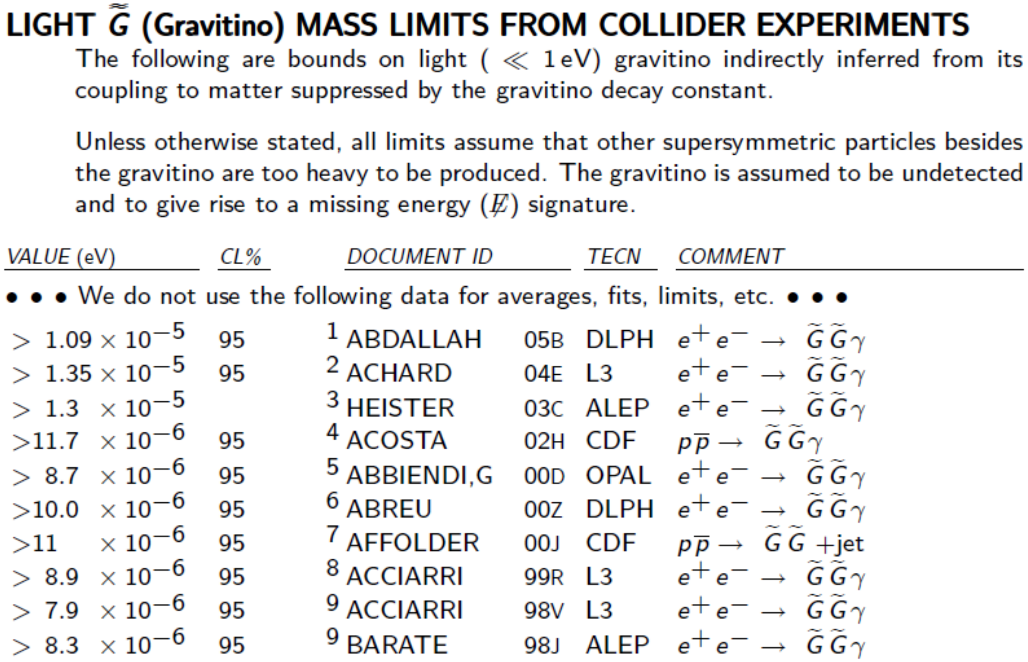


$\chi_{c2}(1P)$ $I^G(J^{PC}) = 0^+(2^{++})$

Mass $m = 3556.20 \pm 0.09$ MeV
Full width $\Gamma = 1.93 \pm 0.11$ MeV

$\chi_{c2}(1P)$ DECAY MODES	Fraction (Γ_i/Γ)	Confidence level	p (MeV/c)
$J/\psi(1S)\pi^+\pi^-\pi^0$	< 1.5 %	90%	185
$\pi^0\eta_c$	$< 3.2 \times 10^{-3}$	90%	512
$\eta_c(1S)\pi^+\pi^-$	$< 5.4 \times 10^{-3}$	90%	459

Citation: K.A. Olive *et al.* (Particle Data Group), Chin. Phys. **C38**, 090001 (2014) (URL: http://pdg.lbl.gov)



LIGHT $\widetilde{G}$ (Gravitino) MASS LIMITS FROM COLLIDER EXPERIMENTS

The following are bounds on light ($\ll$ 1 eV) gravitino indirectly inferred from its coupling to matter suppressed by the gravitino decay constant.

Unless otherwise stated, all limits assume that other supersymmetric particles besides the gravitino are too heavy to be produced. The gravitino is assumed to be undetected and to give rise to a missing energy ($\not{E}$) signature.

VALUE (eV)	*CL%*	*DOCUMENT ID*		*TECN*	*COMMENT*
• • • We do not use the following data for averages, fits, limits, etc. • • •					
$> 1.09 \times 10^{-5}$	95	[1] ABDALLAH	05B	DLPH	$e^+e^- \to \widetilde{G}\widetilde{G}\gamma$
$> 1.35 \times 10^{-5}$	95	[2] ACHARD	04E	L3	$e^+e^- \to \widetilde{G}\widetilde{G}\gamma$
$> 1.3 \times 10^{-5}$		[3] HEISTER	03C	ALEP	$e^+e^- \to \widetilde{G}\widetilde{G}\gamma$
$> 11.7 \times 10^{-6}$	95	[4] ACOSTA	02H	CDF	$p\overline{p} \to \widetilde{G}\widetilde{G}\gamma$
$> 8.7 \times 10^{-6}$	95	[5] ABBIENDI,G	00D	OPAL	$e^+e^- \to \widetilde{G}\widetilde{G}\gamma$
$> 10.0 \times 10^{-6}$	95	[6] ABREU	00Z	DLPH	$e^+e^- \to \widetilde{G}\widetilde{G}\gamma$
$> 11 \times 10^{-6}$	95	[7] AFFOLDER	00J	CDF	$p\overline{p} \to \widetilde{G}\widetilde{G}$ +jet
$> 8.9 \times 10^{-6}$	95	[8] ACCIARRI	99R	L3	$e^+e^- \to \widetilde{G}\widetilde{G}\gamma$
$> 7.9 \times 10^{-6}$	95	[9] ACCIARRI	98V	L3	$e^+e^- \to \widetilde{G}\widetilde{G}\gamma$
$> 8.3 \times 10^{-6}$	95	[9] BARATE	98J	ALEP	$e^+e^- \to \widetilde{G}\widetilde{G}\gamma$

e+e->(J/psi) ->$\tilde{G}$ + $\tilde{G}$ + γ

Quarkonium decay into photon plus graviton: a golden channel to discriminate General Relativity from Massive Gravity?

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(Dated: November 27, 2017)

Abstract

After the recent historical discovery of gravitational wave, it is curious to speculate upon the detection prospect of the quantum graviton in the terrestrial accelerator-based experiment. We carefully investigate the "golden" channels, $J/\psi(\Upsilon) \to \gamma+$graviton, which can be pursued at BESIII and Belle 2 experiments, by searching for single-photon plus missing energy events. Within the effective field theory (EFT) framework of General Relativity (GR) together with Nonrelativistic QCD (NRQCD), we are capable of making solid predictions for the corresponding decay rates. It is found that these extremely suppressed decays are completely swamped by the Standard Model background events $J/\psi(\Upsilon) \to \gamma + \nu\bar{\nu}$. Meanwhile, we also study these rare decay processes in the context of massive gravity, and find the respective decay rates in the limit of vanishing graviton mass drastically differ from their counterparts in GR. Counterintuitive as the failure of smoothly recovering GR results may look, our finding is reminiscent of the van Dam-Veltman-Zakharov (vDVZ) discontinuity widely known in classical gravity, which can be traced to the finite contribution of the helicity-zero graviton in the massless limit. Nevertheless, at this stage we are not certain about the fate of the discontinuity encountered in this work, whether it is merely a pathology or not. If it could be endowed with some physical significance, the future observation of these rare decay channels, would, in principle, shed important light on the nature of gravitation, whether the graviton is strictly massless, or bears a very small but nonzero mass.

PACS numbers: *04.60.Bc, 14.40.Pq, 14.70.Kv*

FIG. 1: Four LO Feynman diagrams for $c\bar{c}({}^3S_1^{(1)}) \to \gamma + \mathcal{G}$.

but I feel, the conclusion of this article is not so much attractive. . .