Dark Matter Searches with ATLAS

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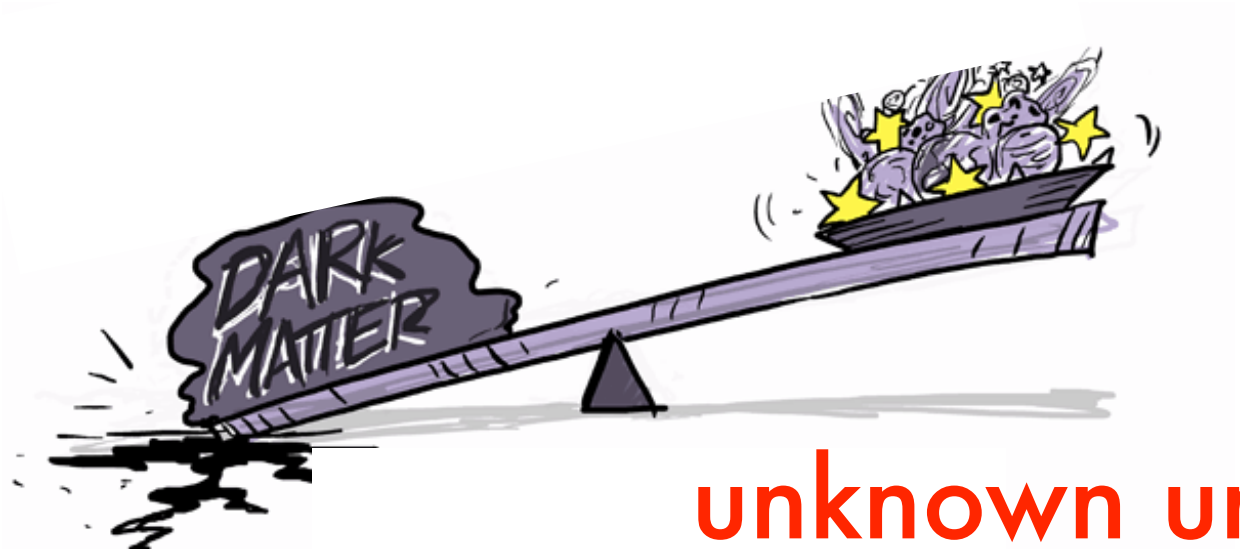
Aspen 2013

What do we know?



unknown unknown

known unknown

known known

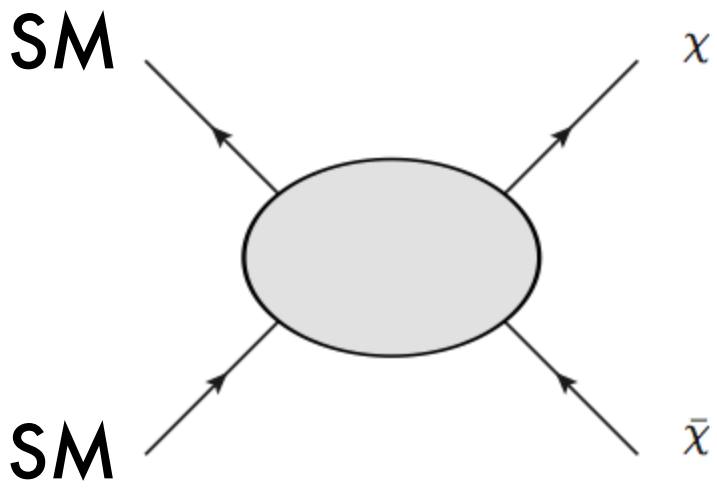
Exploration machine

We can create new forms of matter, *even if we have little or no idea of what we are looking for!*

Interactions

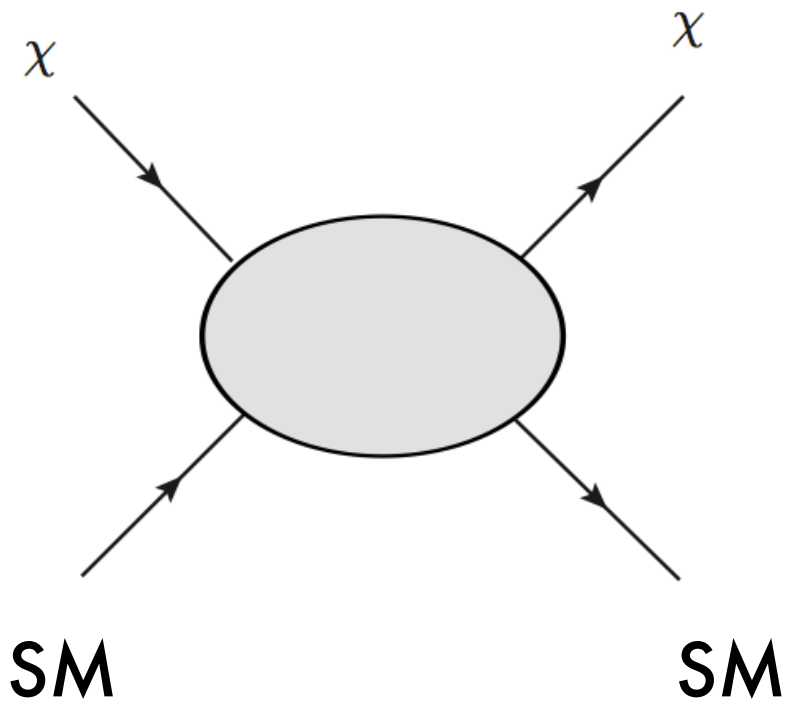
Important assumption:

Requires **some** interaction with SM

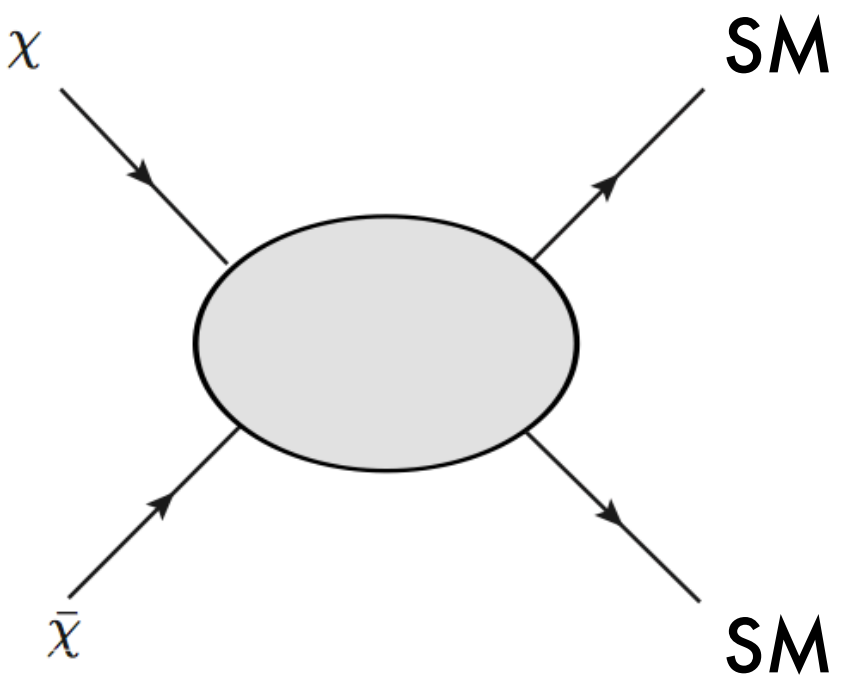


Other experiments

Direct
(Xenon etc)

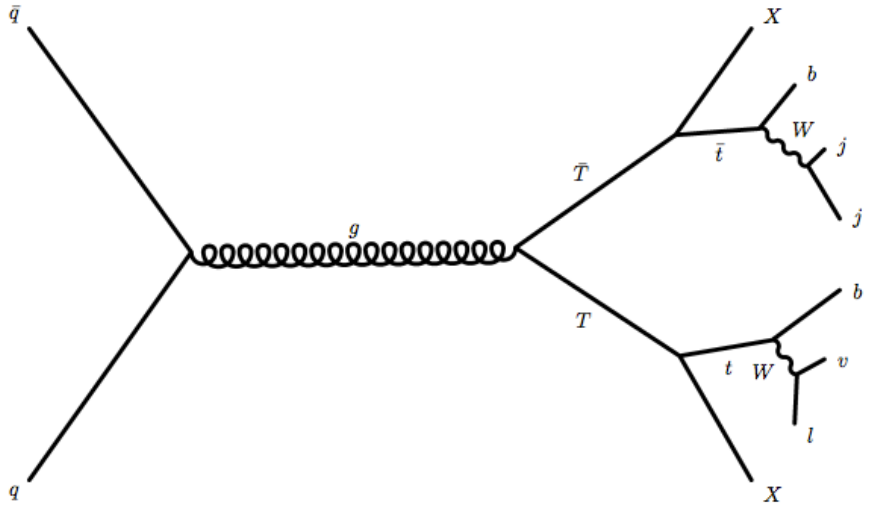


Indirect
(FermiLAT etc)

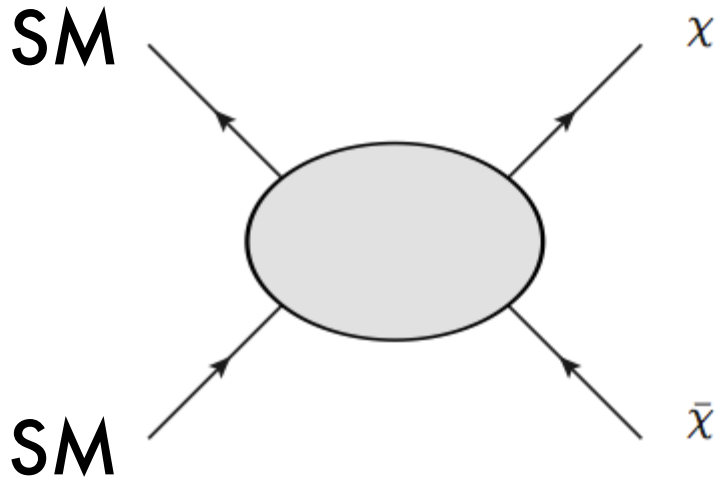


Production

Heavier colored production...



Direct weak production...



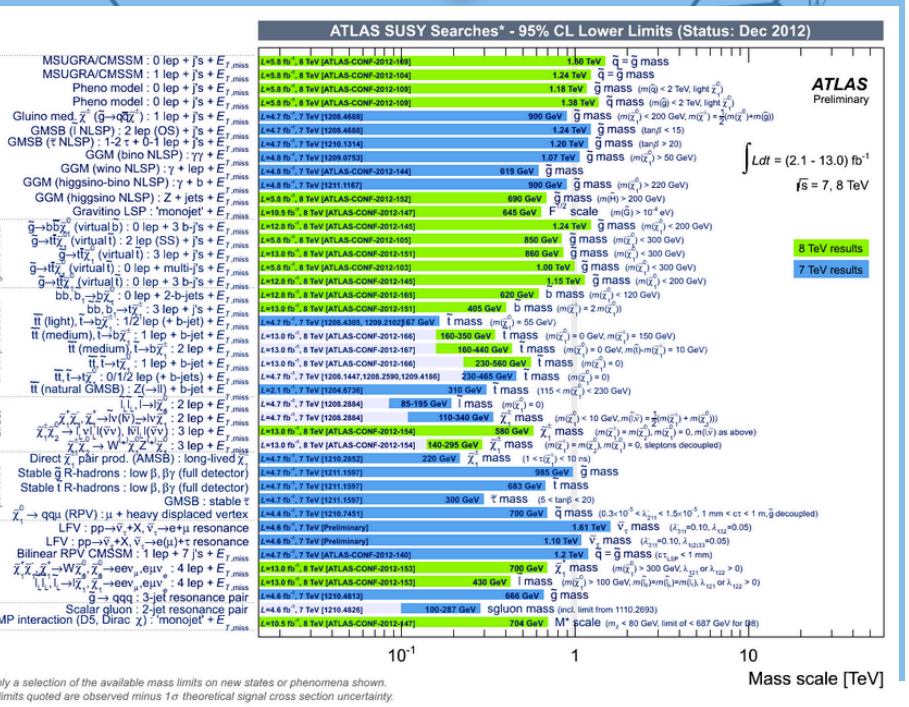
...followed by cascade to WIMPs

..via intermediate heavy particle

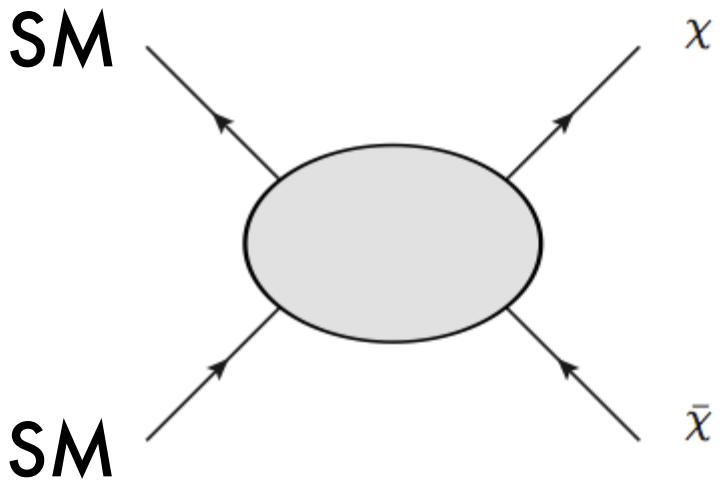
Production

Heavier colored production...

Not discussed today



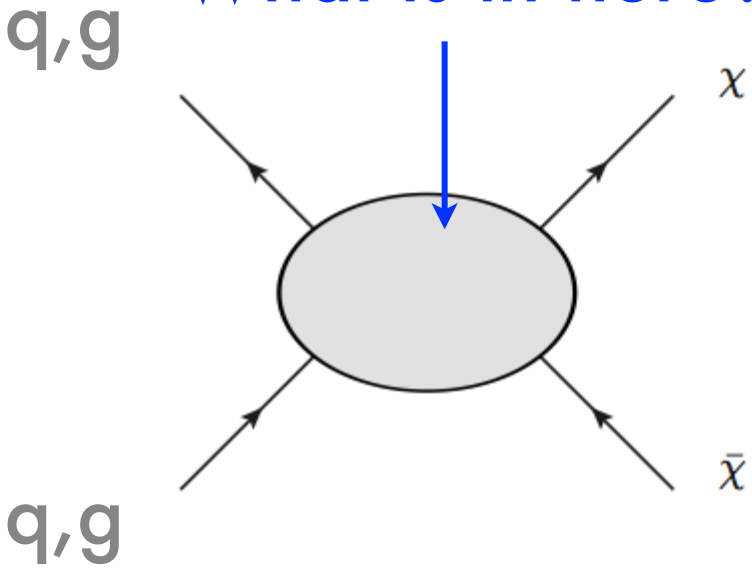
Direct weak production...



..via intermediate heavy particle

Effective field theories

What is in here?



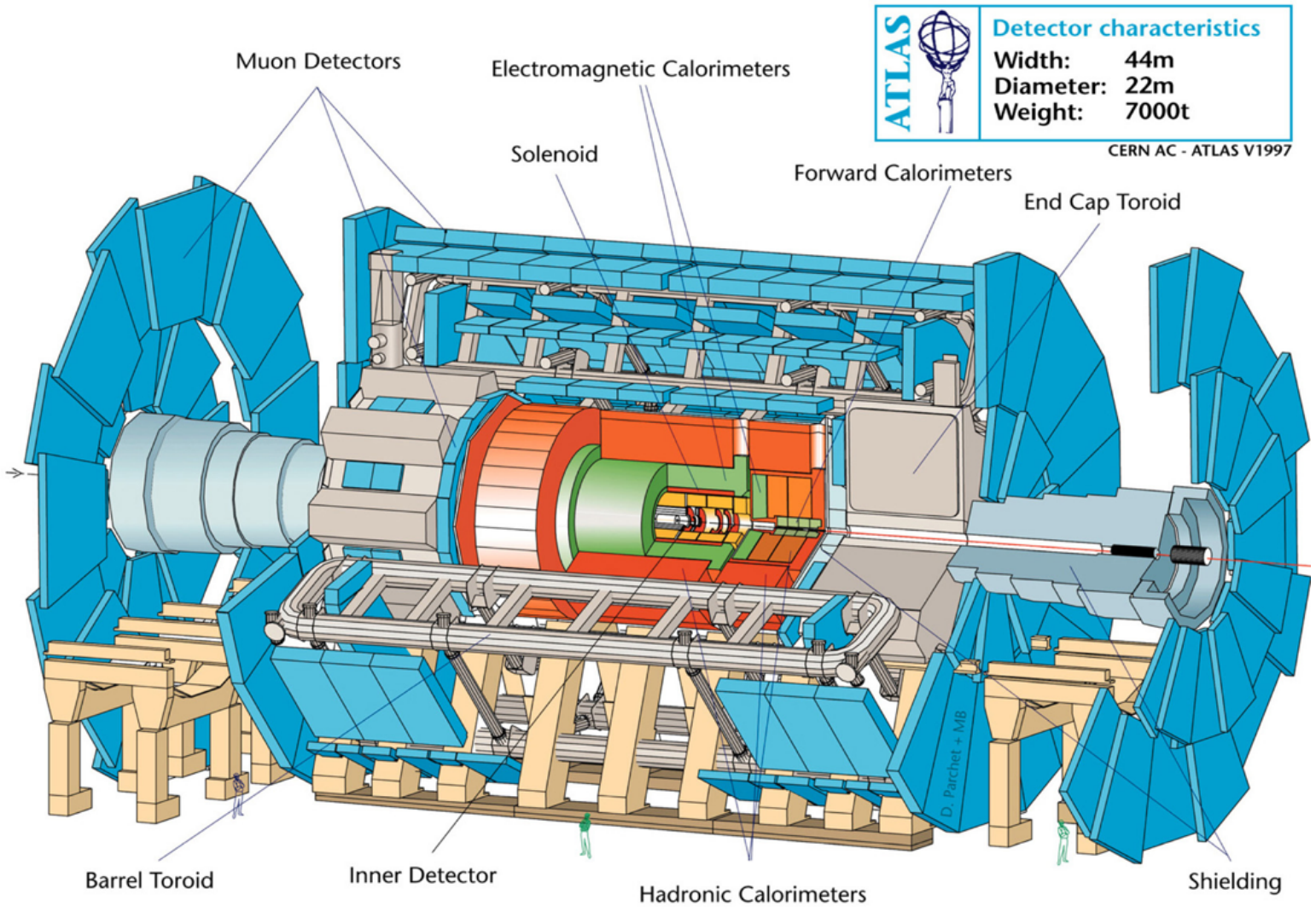
Allows connections to direct, indirect exp.

$$\sigma_0^{D1} = 1.60\times10^{-37}\mathrm{cm}^2\left(\frac{\mu_\chi}{1\mathrm{GeV}}\right)^2\left(\frac{20\mathrm{GeV}}{M_*}\right)^6,$$
$$\sigma_0^{D5,C3} = 1.38\times10^{-37}\mathrm{cm}^2\left(\frac{\mu_\chi}{1\mathrm{GeV}}\right)^2\left(\frac{300\mathrm{GeV}}{M_*}\right)^4,$$
$$\sigma_0^{D8,D9} = 9.18\times10^{-40}\mathrm{cm}^2\left(\frac{\mu_\chi}{1\mathrm{GeV}}\right)^2\left(\frac{300\mathrm{GeV}}{M_*}\right)^4,$$
$$\sigma_0^{D11} = 3.83\times10^{-41}\mathrm{cm}^2\left(\frac{\mu_\chi}{1\mathrm{GeV}}\right)^2\left(\frac{100\mathrm{GeV}}{M_*}\right)^6,$$
$$\sigma_0^{C1,R1} = 2.56\times10^{-36}\mathrm{cm}^2\left(\frac{\mu_\chi}{1\mathrm{GeV}}\right)^2\left(\frac{10\mathrm{GeV}}{m_\chi}\right)^2\left(\frac{10\mathrm{GeV}}{M_*}\right)^4,$$
$$\sigma_0^{C5,R3} = 7.40\times10^{-39}\mathrm{cm}^2\left(\frac{\mu_\chi}{1\mathrm{GeV}}\right)^2\left(\frac{10\mathrm{GeV}}{m_\chi}\right)^2\left(\frac{60\mathrm{GeV}}{M_*}\right)^4.$$

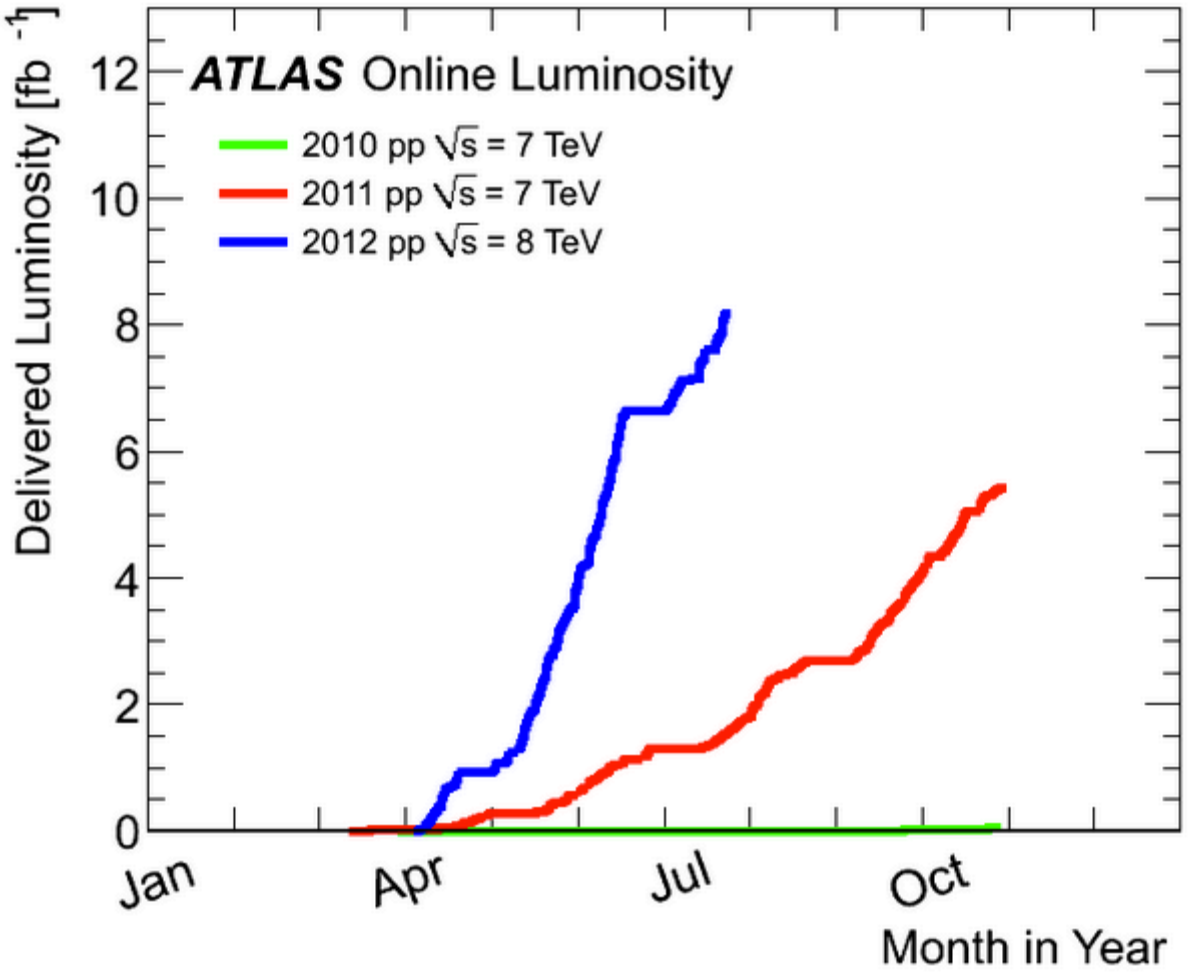
A few possibilities

Name	Operator	Coefficient
D1	$\bar{\chi}\chi\bar{q}q$	m_q/M_*^3
D2	$\bar{\chi}\gamma^5\chi\bar{q}q$	im_q/M_*^3
D3	$\bar{\chi}\chi\bar{q}\gamma^5q$	im_q/M_*^3
D4	$\bar{\chi}\gamma^5\chi\bar{q}\gamma^5q$	m_q/M_*^3
D5	$\bar{\chi}\gamma^\mu\chi\bar{q}\gamma_\mu q$	$1/M_*^2$
D6	$\bar{\chi}\gamma^\mu\gamma^5\chi\bar{q}\gamma_\mu q$	$1/M_*^2$
D7	$\bar{\chi}\gamma^\mu\chi\bar{q}\gamma_\mu\gamma^5q$	$1/M_*^2$
D8	$\bar{\chi}\gamma^\mu\gamma^5\chi\bar{q}\gamma_\mu\gamma^5q$	$1/M_*^2$
D9	$\bar{\chi}\sigma^{\mu\nu}\chi\bar{q}\sigma_{\mu\nu}q$	$1/M_*^2$
D10	$\bar{\chi}\sigma_{\mu\nu}\gamma^5\chi\bar{q}\sigma_{\alpha\beta}q$	i/M_*^2
D11	$\bar{\chi}\chi G_{\mu\nu}G^{\mu\nu}$	$\alpha_s/4M_*^3$
D12	$\bar{\chi}\gamma^5\chi G_{\mu\nu}G^{\mu\nu}$	$i\alpha_s/4M_*^3$
D13	$\bar{\chi}\chi G_{\mu\nu}\tilde{G}^{\mu\nu}$	$i\alpha_s/4M_*^3$
D14	$\bar{\chi}\gamma^5\chi G_{\mu\nu}\tilde{G}^{\mu\nu}$	$\alpha_s/4M_*^3$

ATLAS

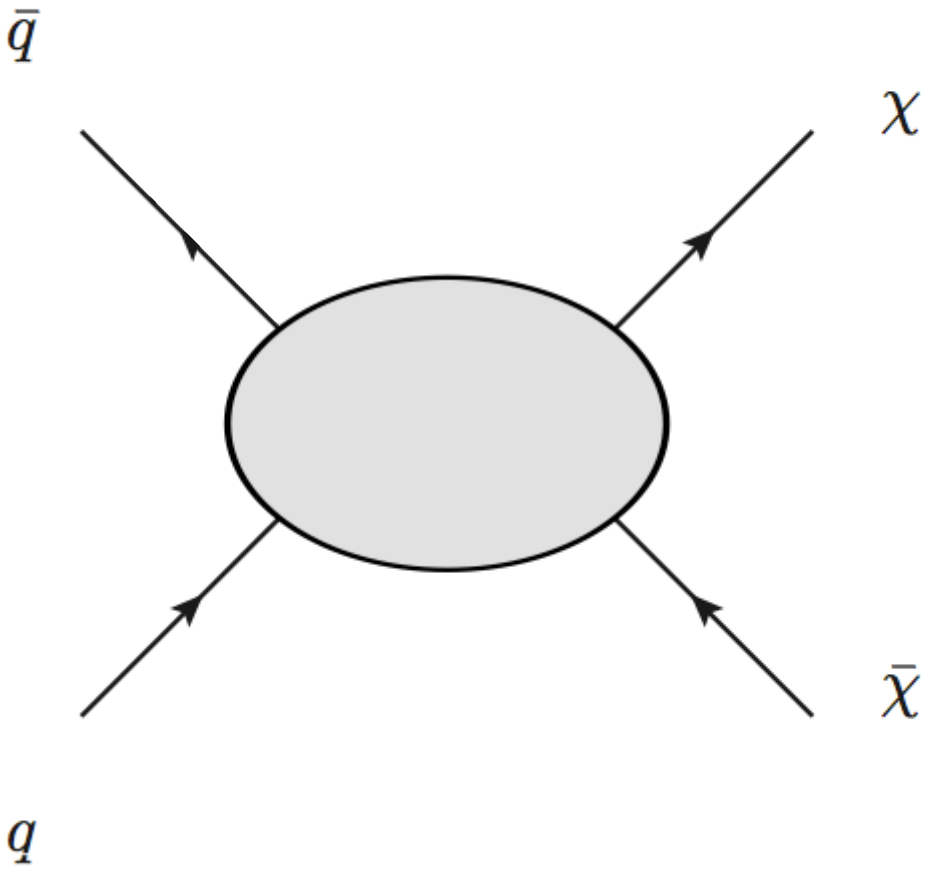

ATLAS
Detector characteristics
Width: 44m
Diameter: 22m
Weight: 7000t
CERN AC - ATLAS V1997
Muon Detectors
Electromagnetic Calorimeters
Solenoid
Forward Calorimeters
End Cap Toroid
Barrel Toroid
Inner Detector
Hadronic Calorimeters
Shielding
D. Parchet + MB

LHC dataset

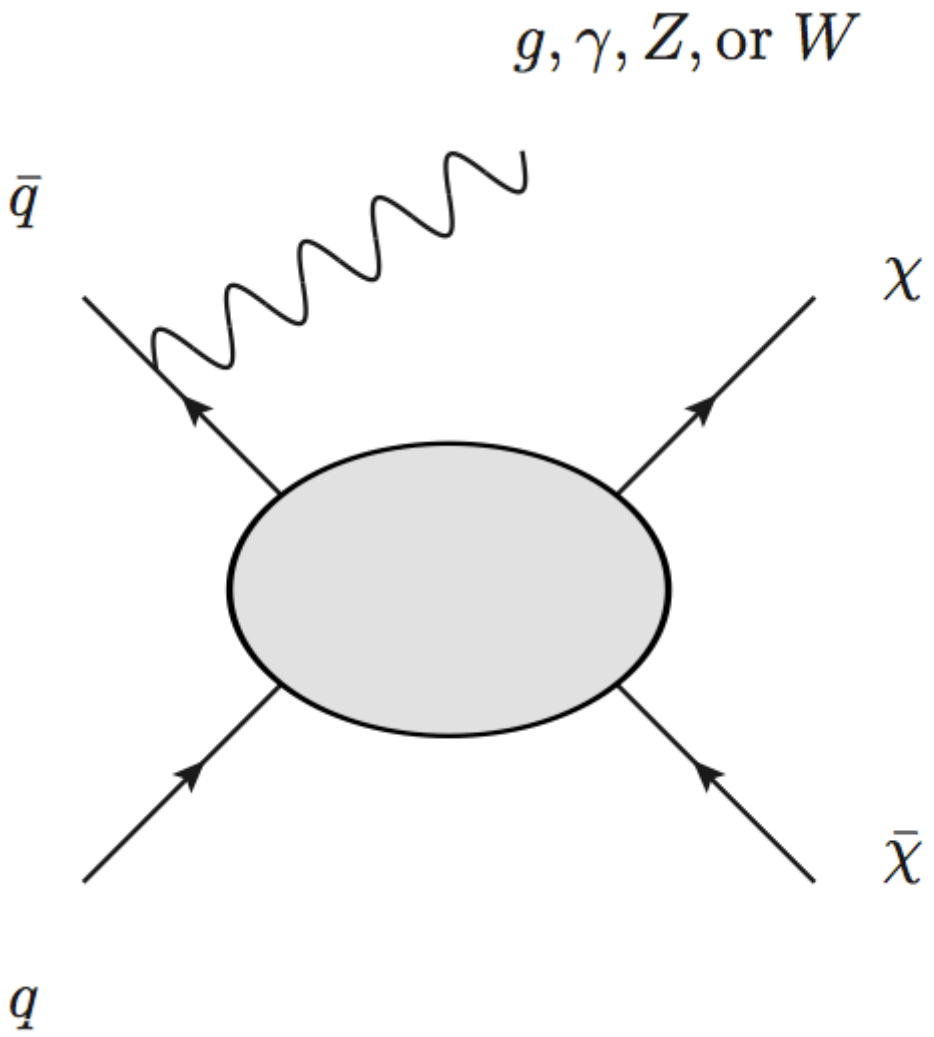


Today's results use 2011 data.

How to see it?



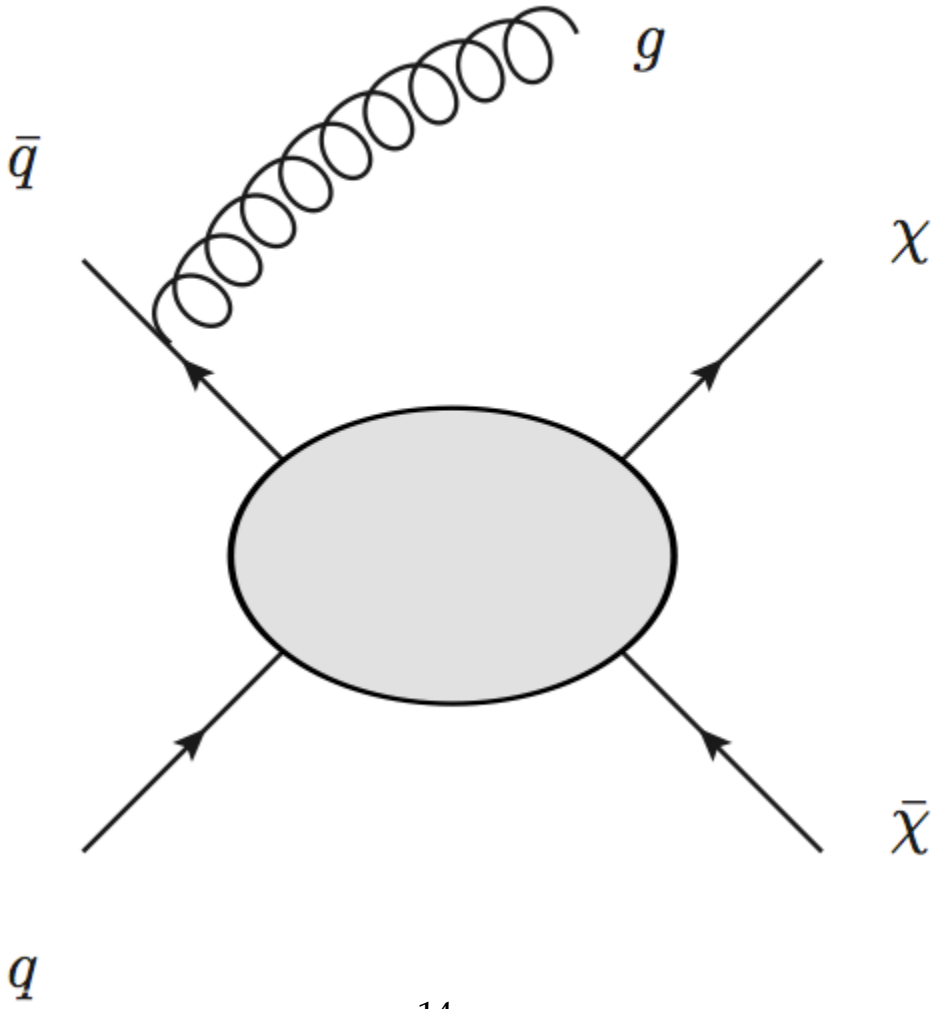
How to see it?



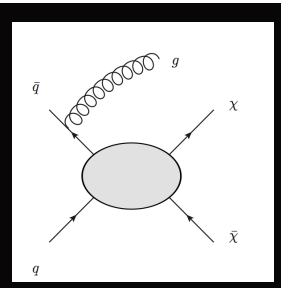
Collider searches

I. Mono-jet
II. Mono-photon

Mono-jet



Mono-jet



ATLAS selection

MET > 350 (500)

1 or 2 jets, p_T> 350(500), 30

veto lepton

dPhi(j_2,MET) > 0.5

Major backgrounds

$Z \rightarrow \nu\nu$+jets

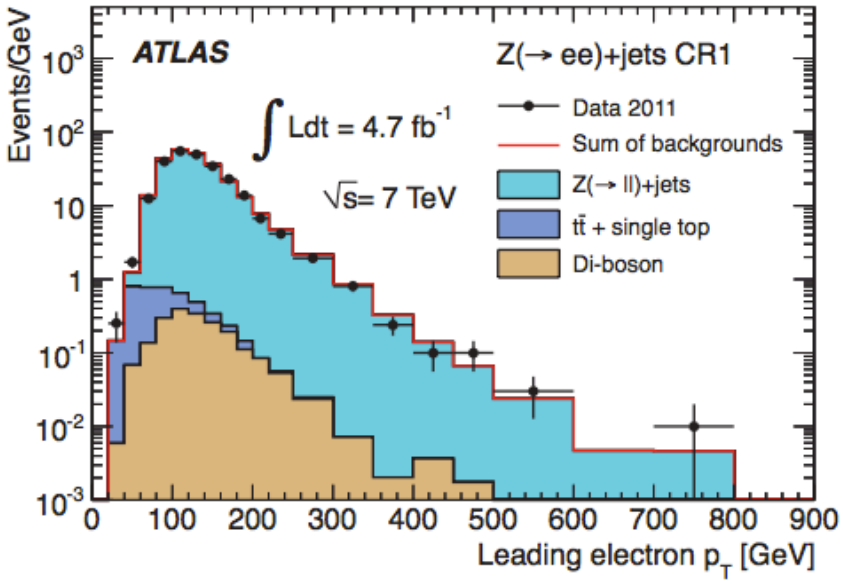
$W \rightarrow l\nu$+jets

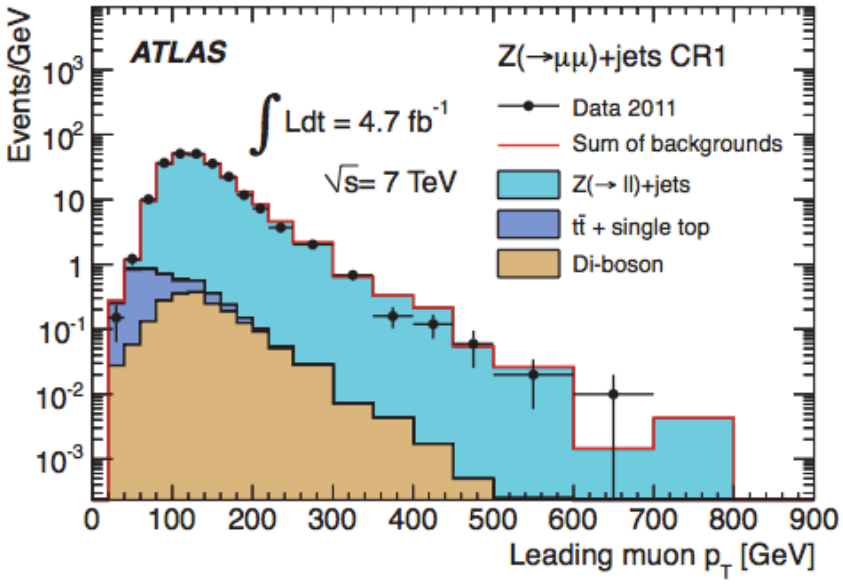
Constrained in data using control regions

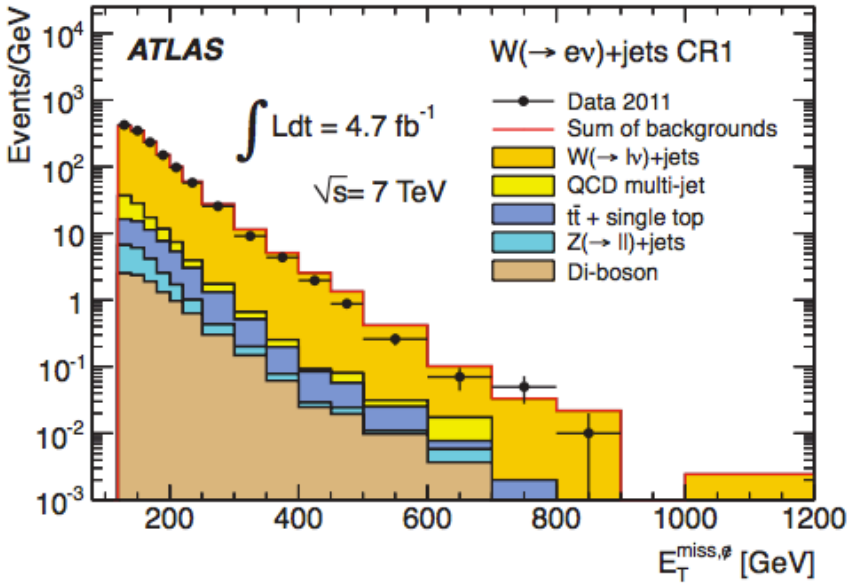
arXiv:1210.4491

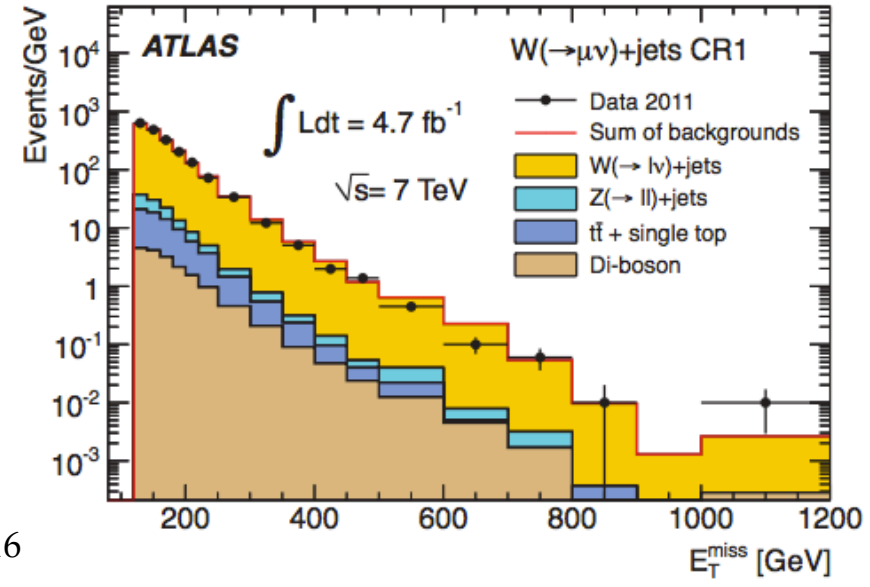
arXiv:1210.4491

Control Regions

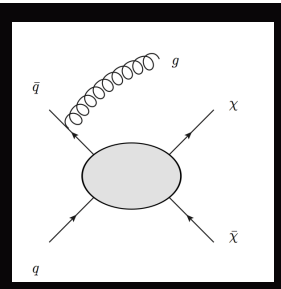








Mono-jet



ATLAS selection

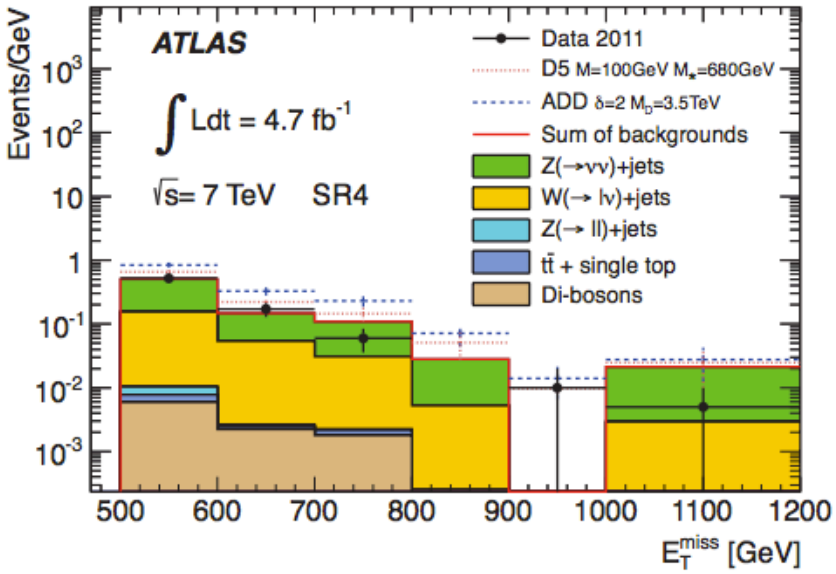
MET > 350 (500)

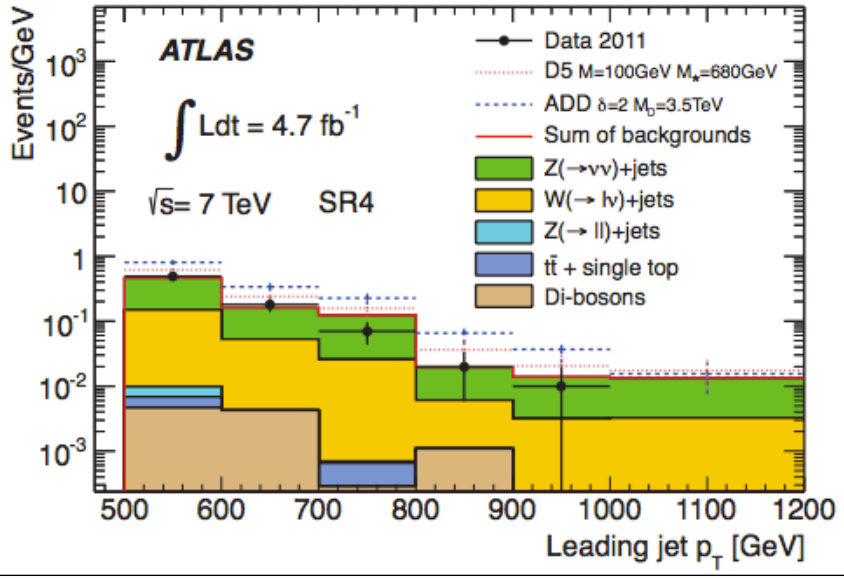
1 or 2 jets, p_T> 350(500), 30

veto lepton

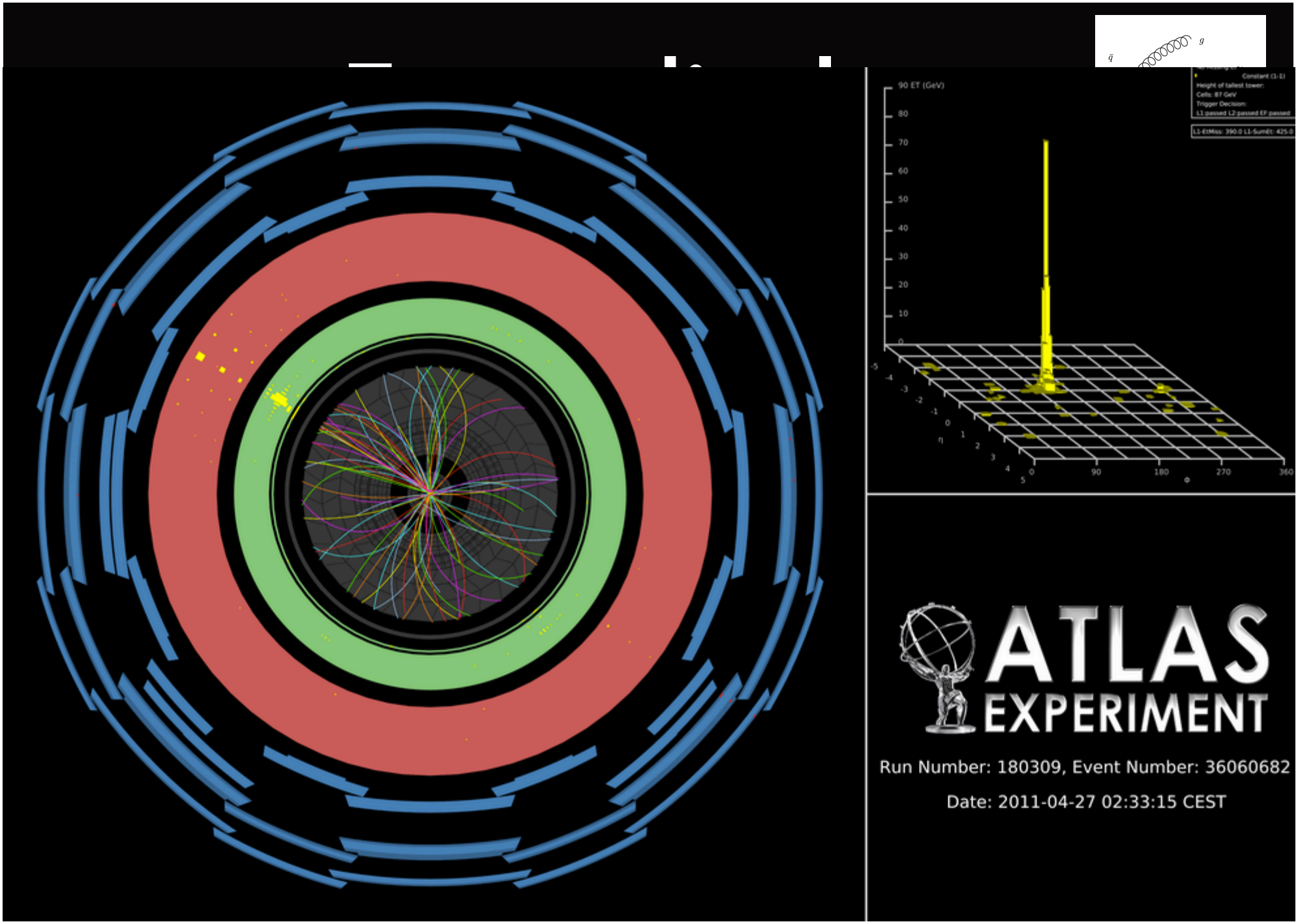
dPhi(j_2,MET) > 0.5

	SR3	SR4
$Z \to \nu\bar{\nu}$+jets	500 ± 40	58 ± 9
$W \to \tau\nu$+jets	133 ± 13	13 ± 3
$W \to e\nu$+jets	40 ± 8	5 ± 2
$W \to \mu\nu$+jets	55 ± 6	6 ± 1
$t\bar{t}$ + single t	4 ± 1	-
Multijets	8^{+9}_{-8}	-
Non-coll. Background	-	-
$Z/\gamma^* \to \tau\tau$+jets	2 ± 1	-
Di-bosons	5 ± 1	1 ± 1
$Z/\gamma^* \to \mu\mu$+jets	-	-
Total Background	750 ± 60	83 ± 14
Events in Data (4.7 fb^{-1})	785	77



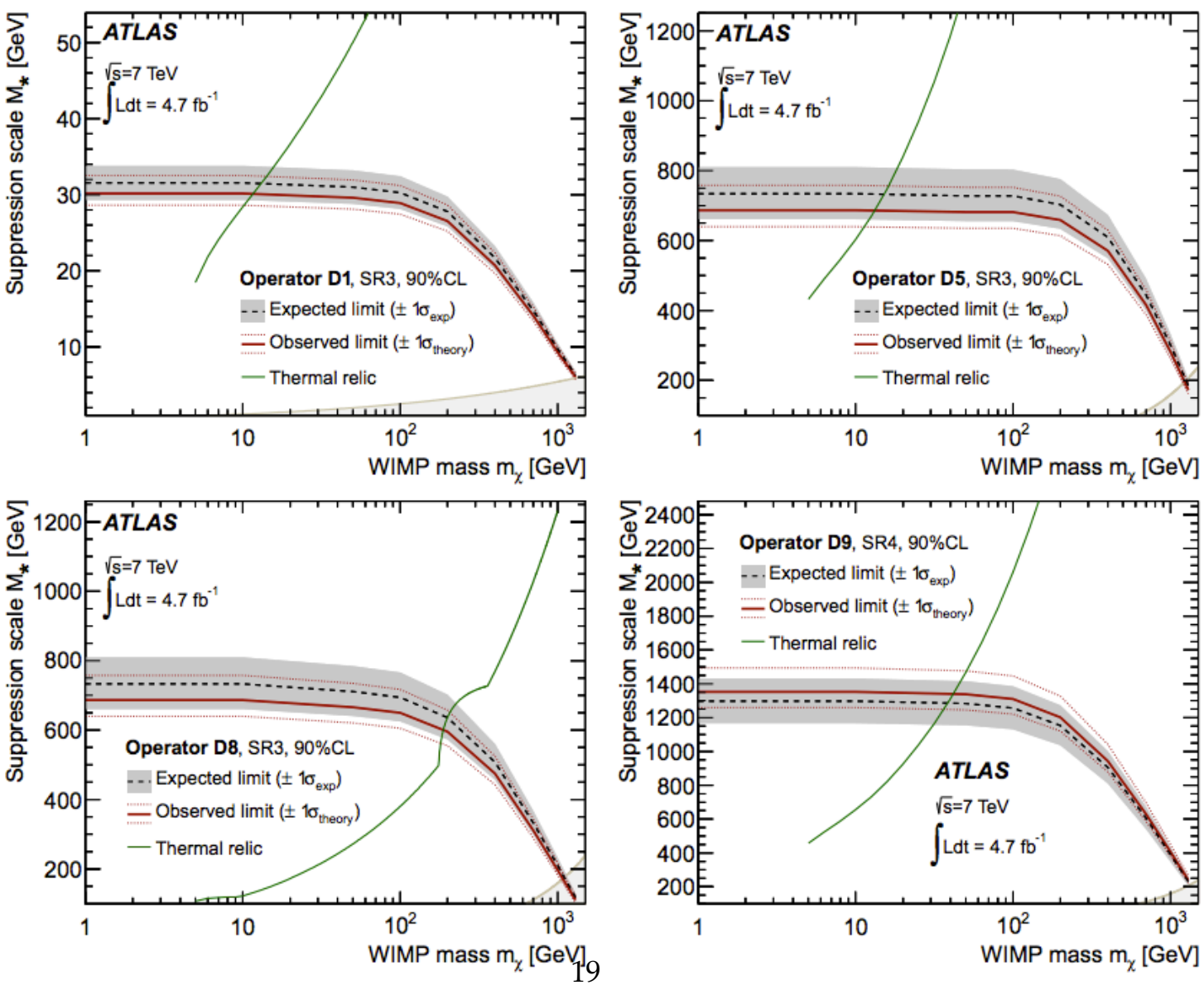


arXiv:1210.4491

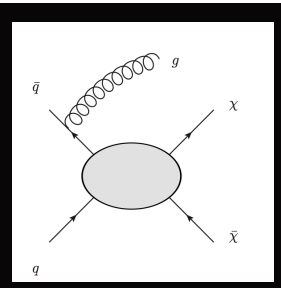

90 ET (GeV)
ATLAS
EXPERIMENT
Run Number: 180309, Event Number: 36060682
Date: 2011-04-27 02:33:15 CEST

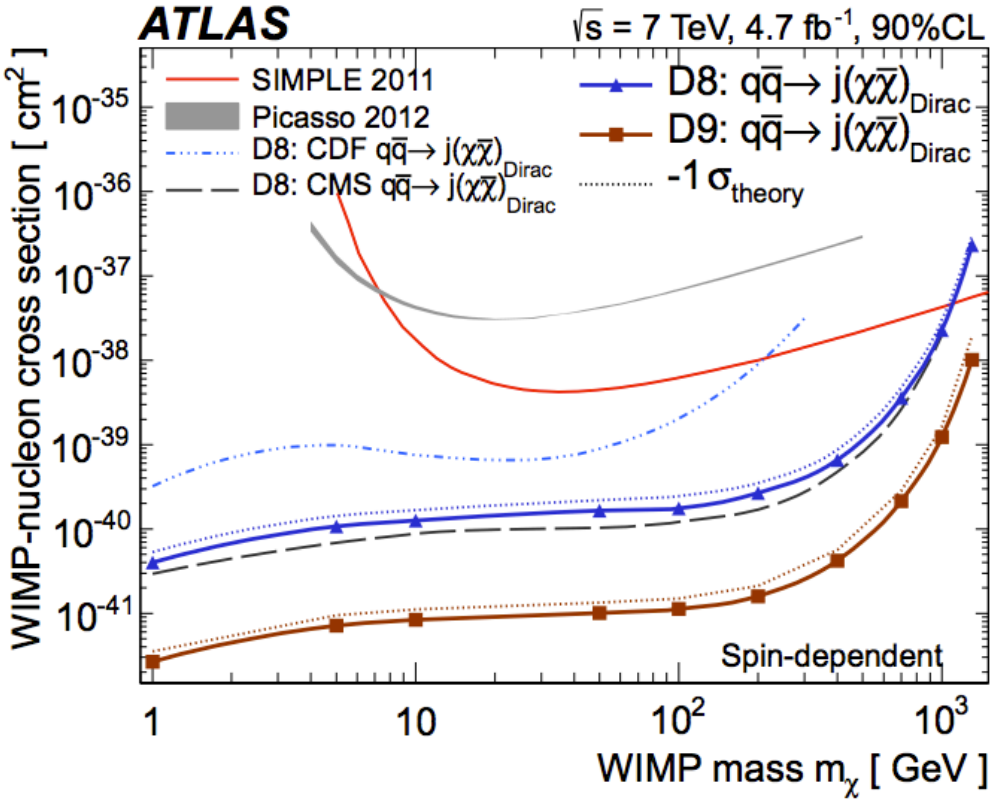
M* limits

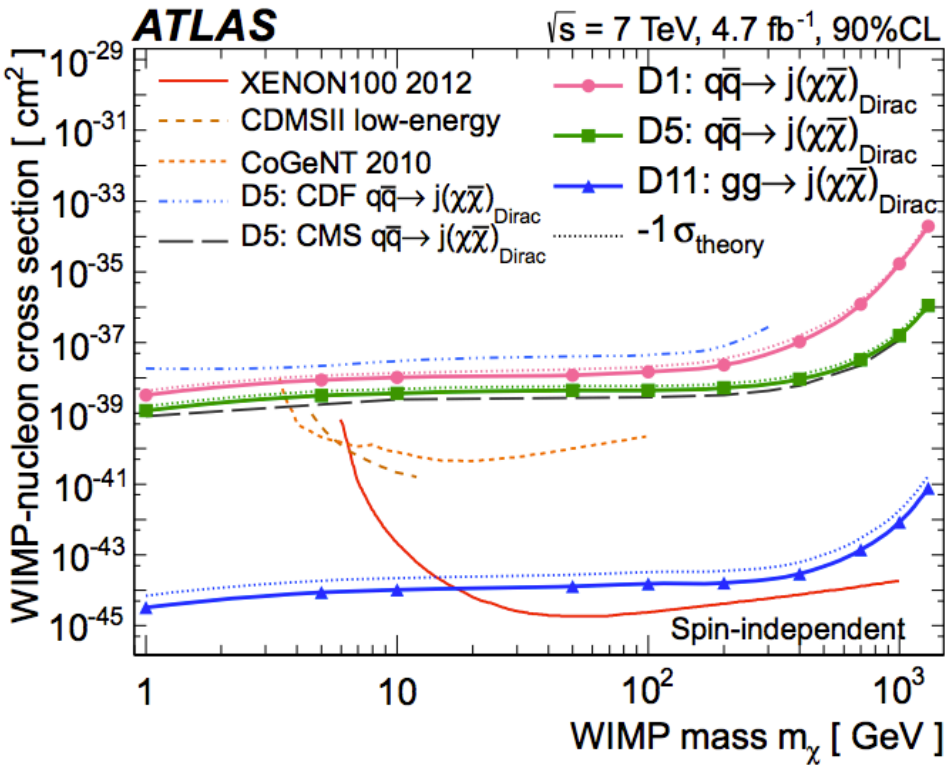
arXiv:1210.4491



Mono-jet limits

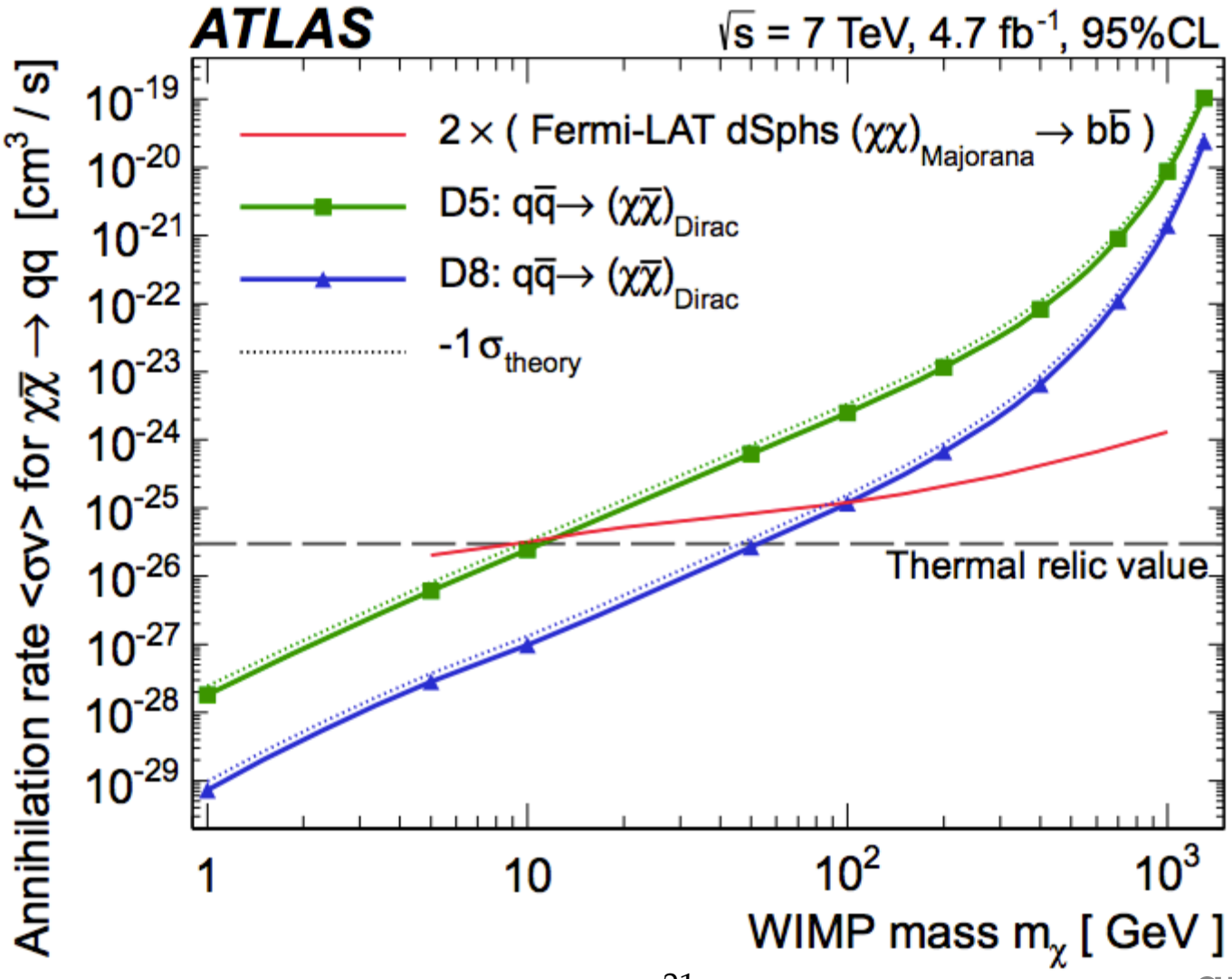






arXiv:1210.4491

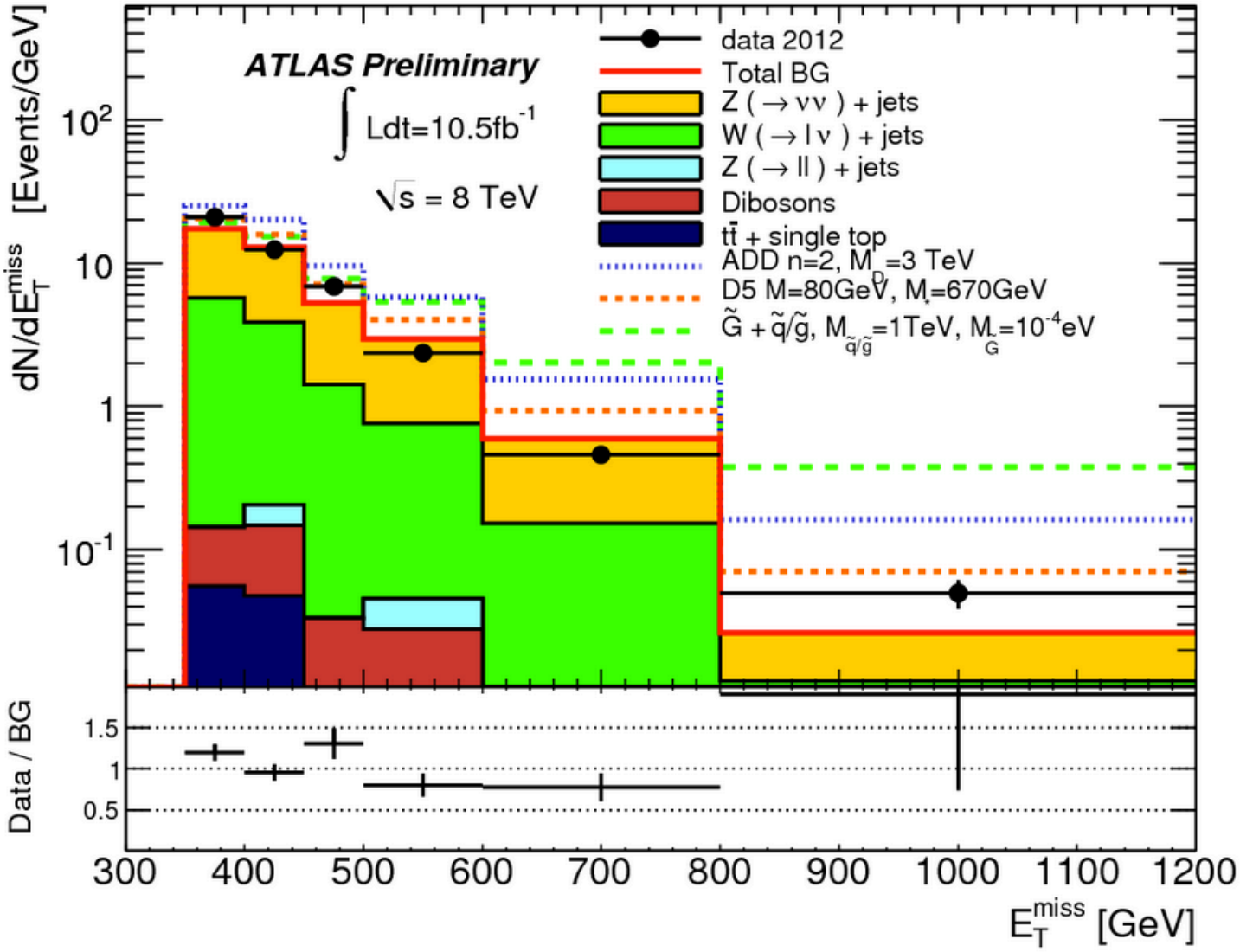
annhiliation rates



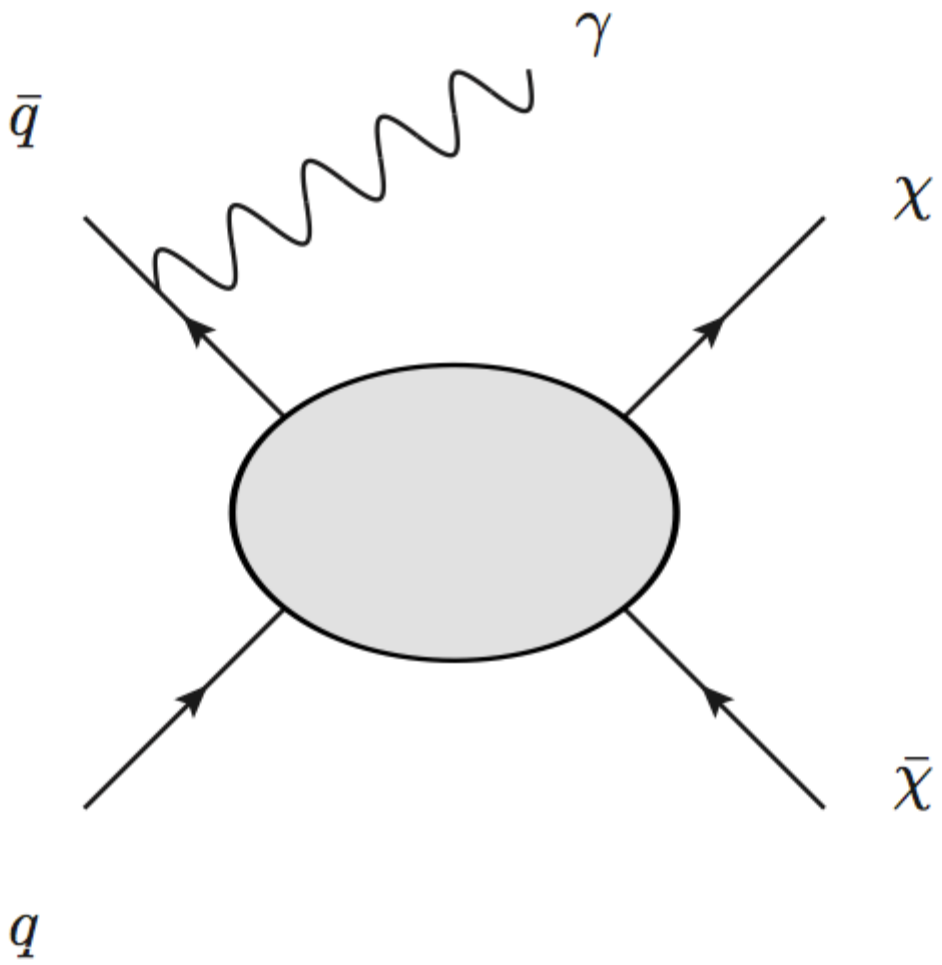
arXiv:1210.4491

8 TeV preliminary

https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2012-147/

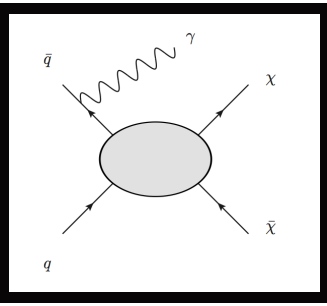


Mono-photon



arXiv:1209.4625

Mono-photon



ATLAS selection

MET > 150
photon p_T>150
0 or 1 jet with p_T>30
0 leptons
Object isolation, separation

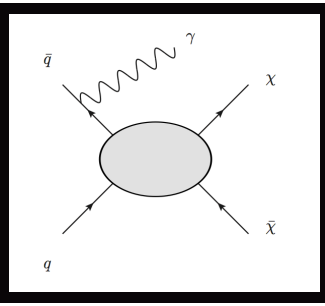
Major backgrounds

Z→νν+photon
W→lν+photon

Constrained in data using control regions

arXiv:1209.4625

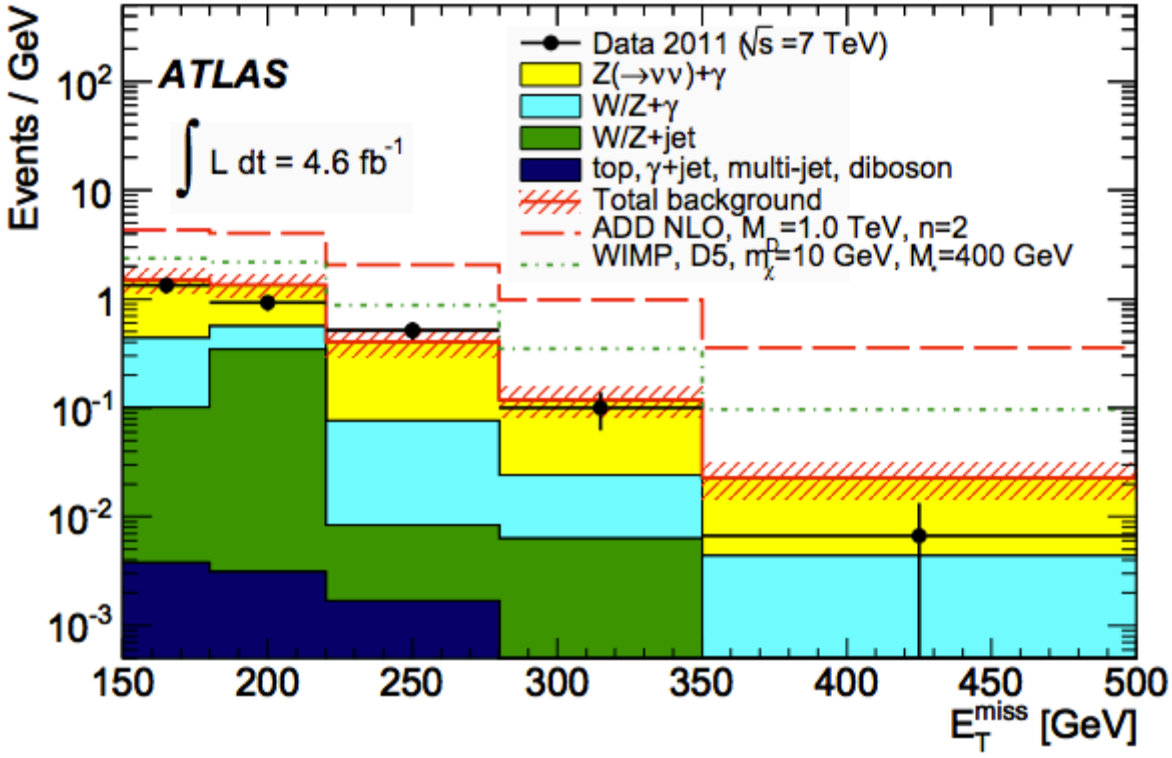
Mono-photon



ATLAS selection

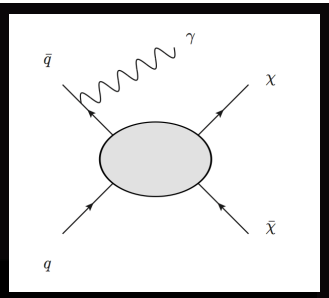
MET > 150
photon p_T>150
0 or 1 jet with p_T>30
0 leptons
Object isolation, separation

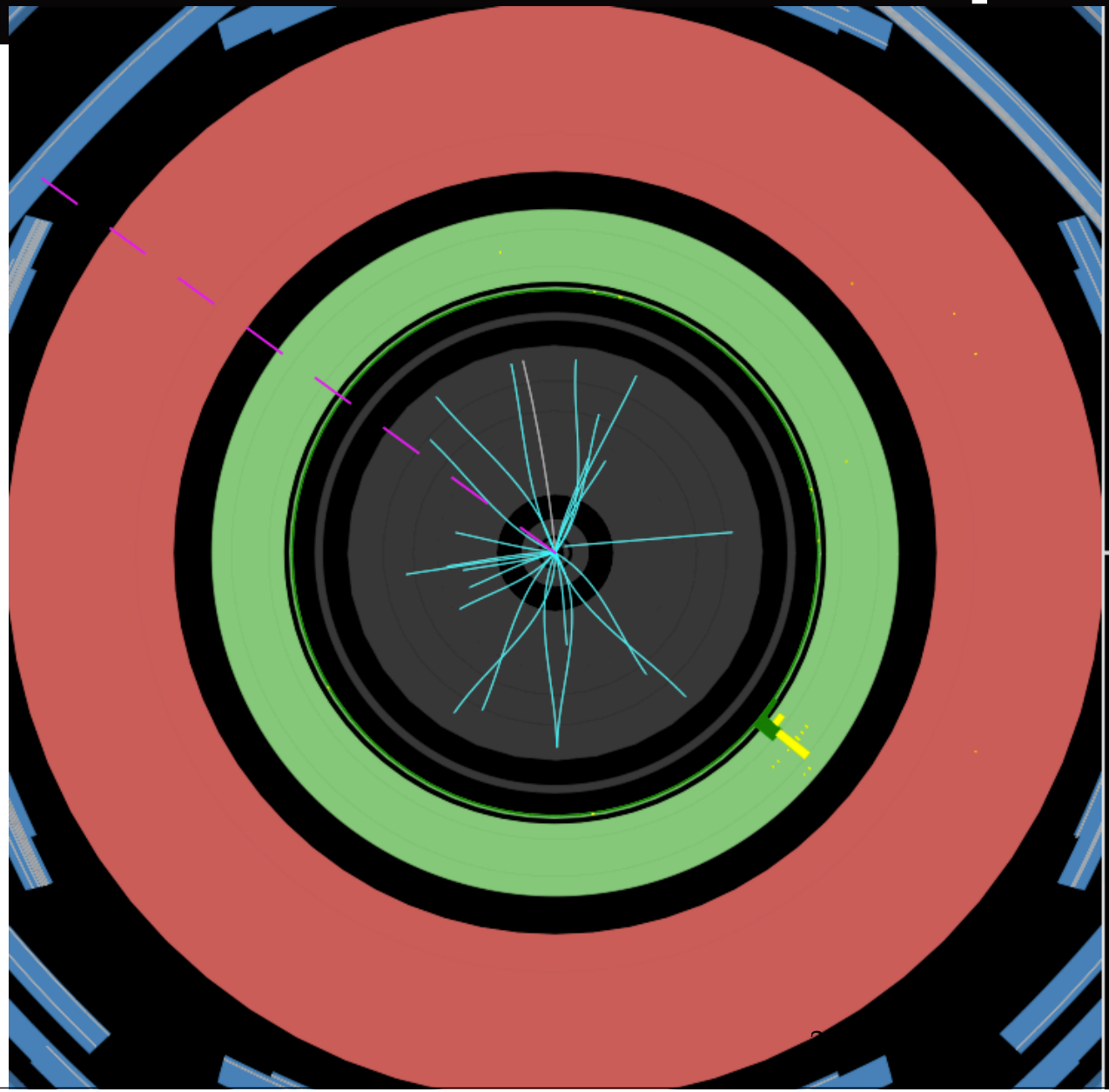
Background source	Prediction	± (stat.)	± (syst
$Z(\to \nu\bar{\nu}) + \gamma$	93	± 16	± 8
$Z/\gamma^*(\to \ell^+\ell^-) + \gamma$	0.4	± 0.2	± 0.1
$W(\to \ell\nu) + \gamma$	24	± 5	± 2
W/Z + jets	18	−	± 6
Top	0.07	± 0.07	± 0.01
$WW, WZ, ZZ, \gamma\gamma$	0.3	± 0.1	± 0.1
γ+jets and multi-jet	1.0	−	± 0.5
Total background	137	± 18	± 9
Events in data (4.6 fb^{-1})	116		

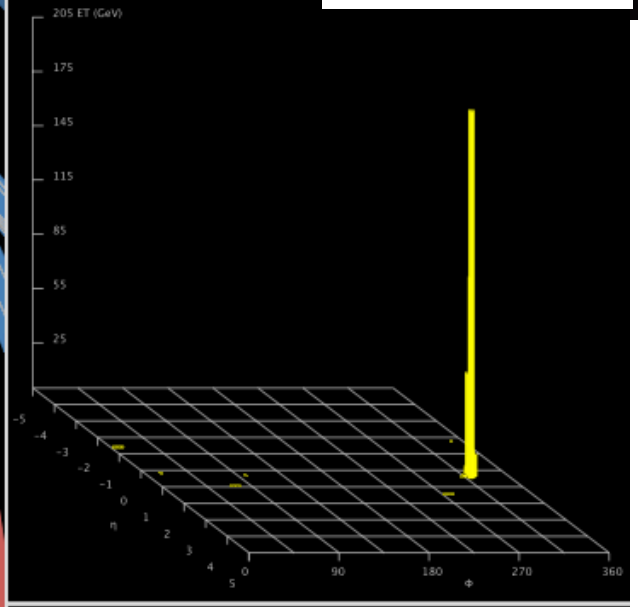


arXiv:1209.4625

Event display





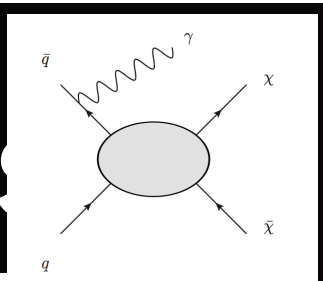


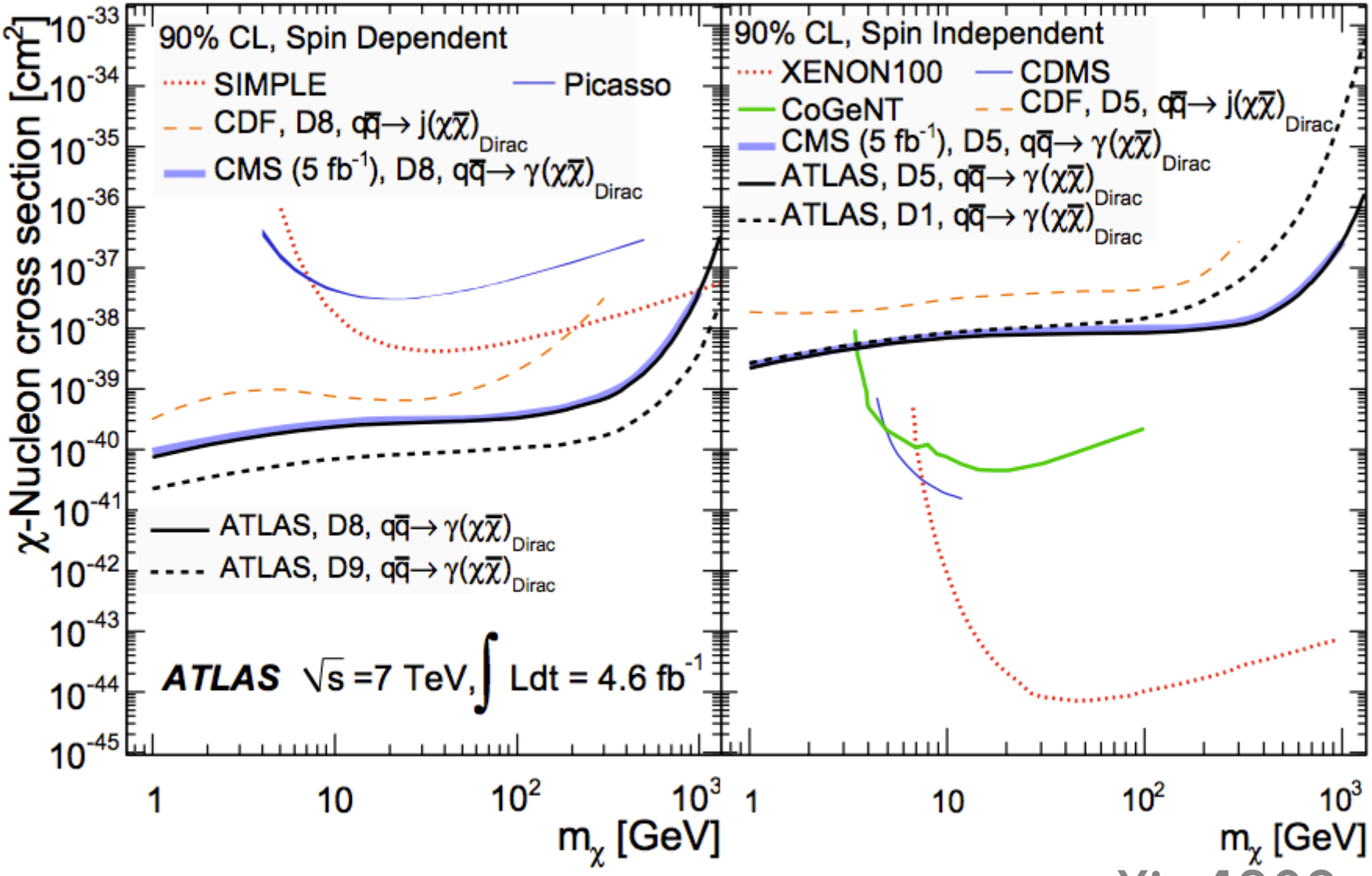
ATLAS EXPERIMENT

Run Number: 179710, Event Number: 19174449

Date: 2011-04-15 03:48:32 CEST

Mono-photon limits





arXiv:1209.4625

Conclusions

Years after DM is postulated, we still know little of its particle nature.

Colliders are a good place to perform broadly sensitive searches.

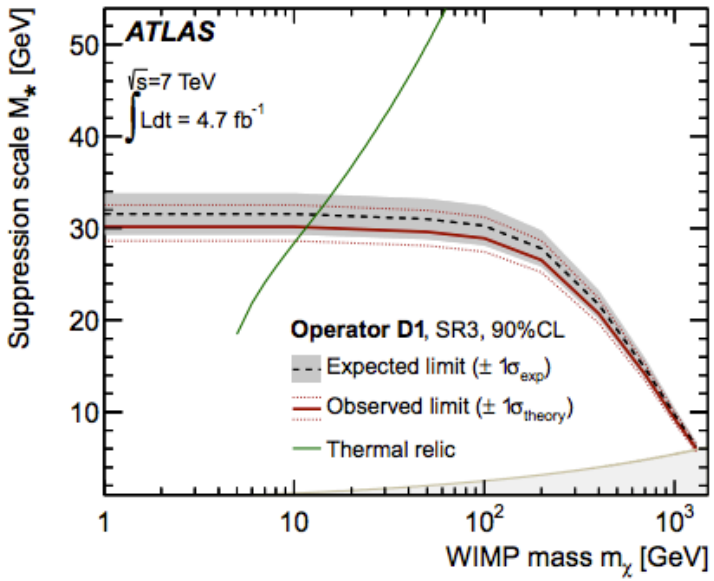
ATLAS provides powerful, multi-faceted probes.

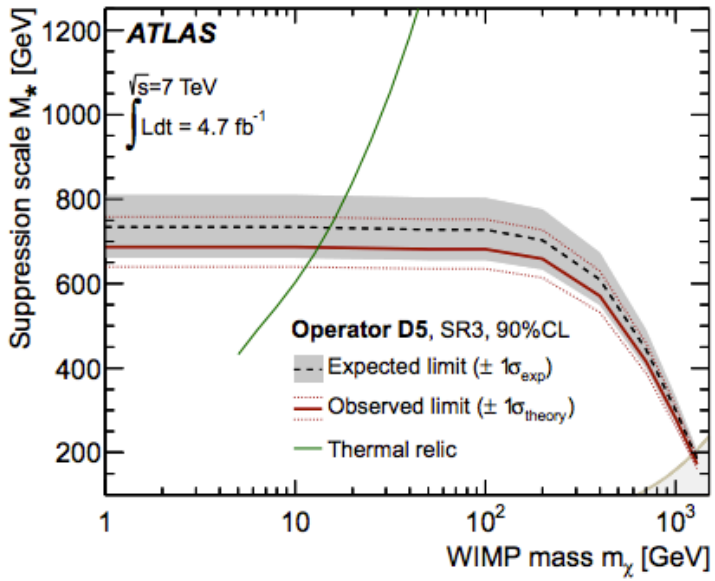
Efficiencies

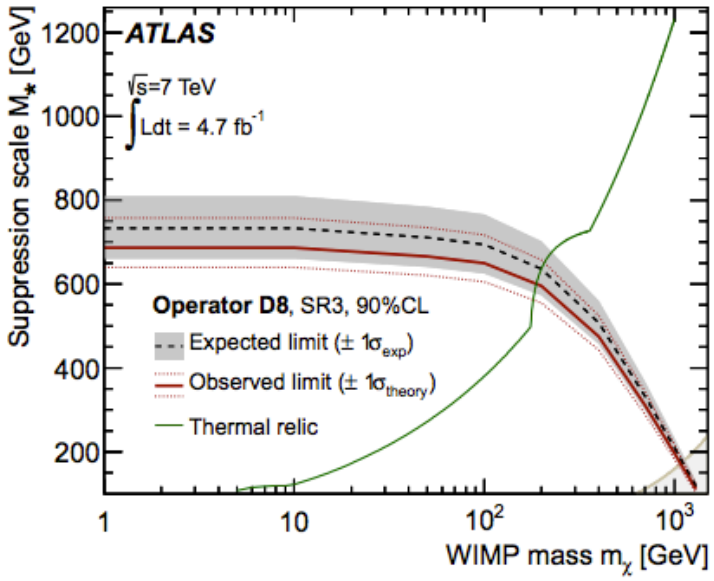
Sample	SR1 [%]	SR2 [%]	SR3 [%]	SR4 [%]
$Z \to \nu\bar{\nu}$+jets	1.706 ± 0.013	0.159 ± 0.004	0.0170 ± 0.0013	0.0027 ± 0.0005
ADD, $n = 2$	30.9 ± 0.2	9.2 ± 0.1	2.60 ± 0.07	0.74 ± 0.04
ADD, $n = 3$	33.2 ± 0.2	11.7 ± 0.1	3.92 ± 0.08	1.18 ± 0.05
ADD, $n = 4$	34.3 ± 0.2	13.8 ± 0.1	4.97 ± 0.09	1.67 ± 0.05
ADD, $n = 5$	35.1 ± 0.2	14.5 ± 0.1	5.50 ± 0.09	2.00 ± 0.06
ADD, $n = 6$	35.0 ± 0.2	15.0 ± 0.2	6.01 ± 0.10	2.23 ± 0.06
D1, $m_\chi = 10$ GeV	20.5 ± 0.3	3.3 ± 0.1	0.54 ± 0.01	0.09 ± 0.01
D1, $m_\chi = 1000$ GeV	32.2 ± 0.4	10.3 ± 0.2	2.88 ± 0.04	0.79 ± 0.02
D5, $m_\chi = 10$ GeV	30.4 ± 0.4	8.3 ± 0.2	2.04 ± 0.03	0.52 ± 0.01
D5, $m_\chi = 1000$ GeV	36.2 ± 0.4	12.6 ± 0.2	4.14 ± 0.05	1.24 ± 0.03
D9, $m_\chi = 10$ GeV	36.9 ± 0.5	12.9 ± 0.3	4.23 ± 0.15	1.31 ± 0.08
D9, $m_\chi = 1000$ GeV	37.6 ± 0.5	13.9 ± 0.3	4.70 ± 0.16	1.68 ± 0.09
D11, $m_\chi = 10$ GeV	30.3 ± 0.4	12.3 ± 0.3	4.57 ± 0.15	1.52 ± 0.09
D11, $m_\chi = 1000$ GeV	33.7 ± 0.5	17.0 ± 0.3	7.56 ± 0.20	3.27 ± 0.13

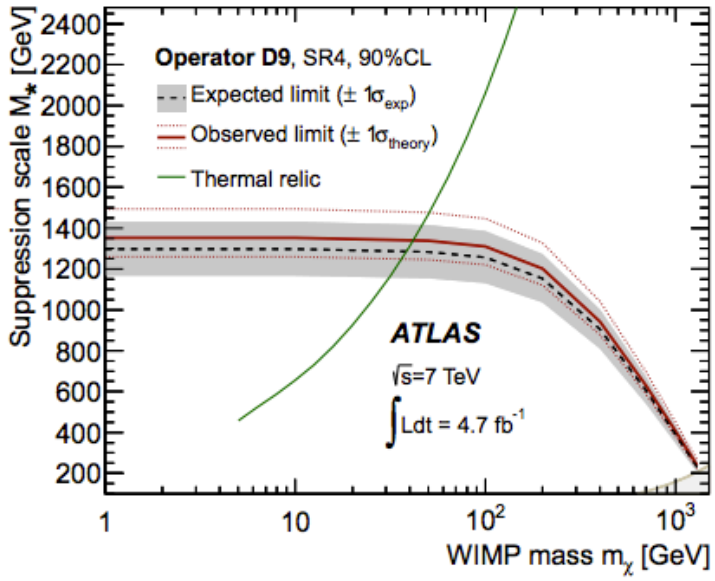
arXiv:1210.4491

M* limits









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