# Search for DM pair production with W & Z boson

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DM at Collider, Chicago
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# Why looking for Dark Matter with W/Z?

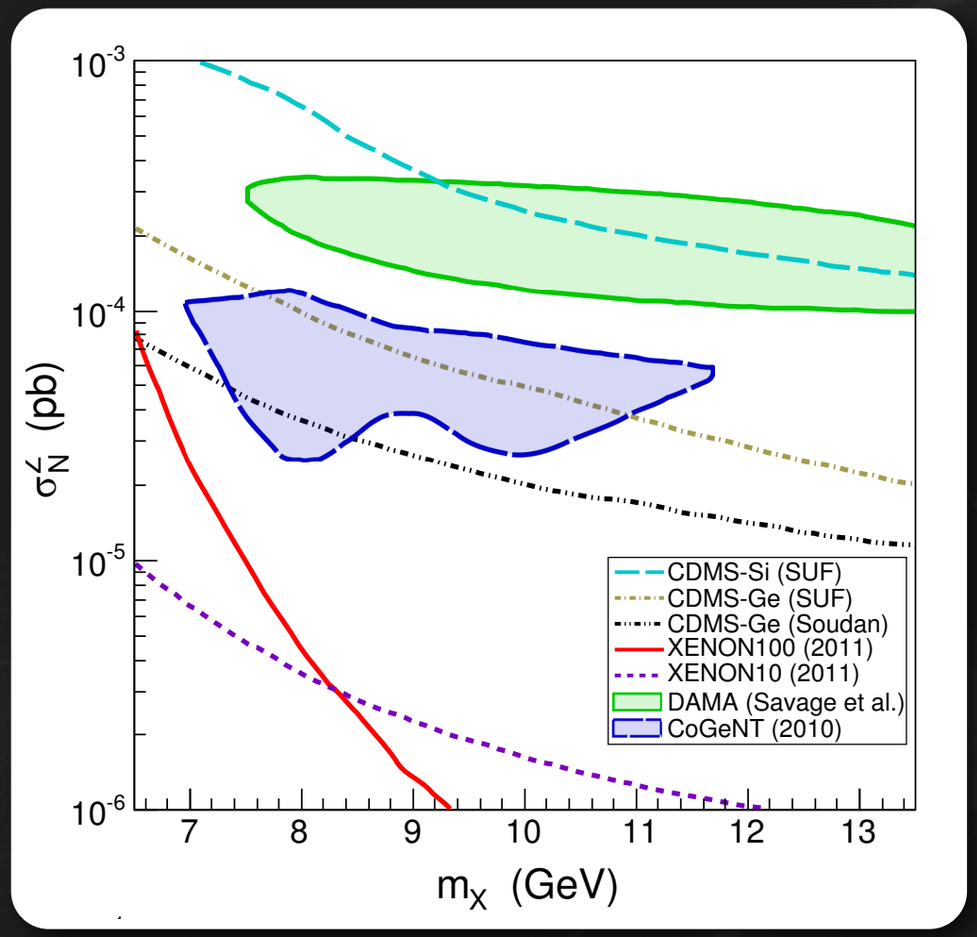
- Typical search channel:
  - mono-jet,
  - mono-photon
- mono-W small rate exp.
  - same couplings up/down-type quarks
- W boson emission may become dominant
  - opposite sign couplings
- Largest BR for hadronic decay



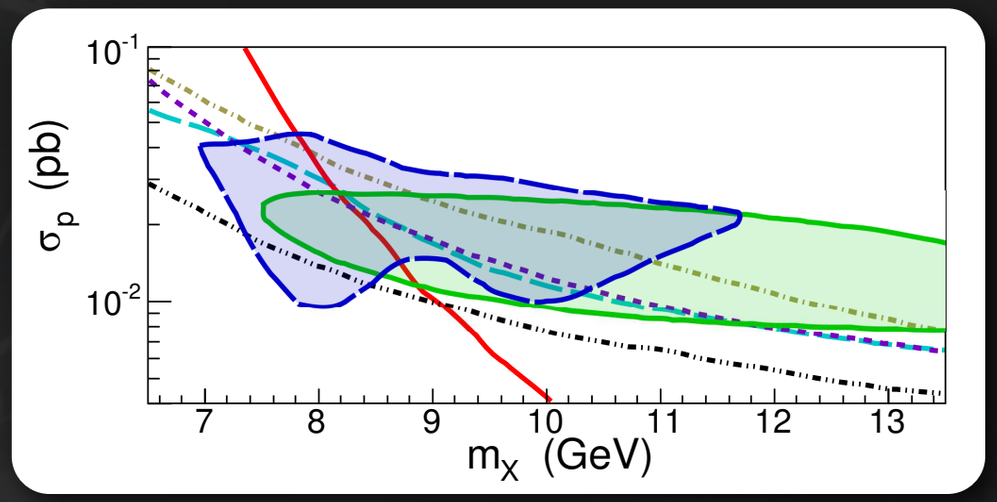
Y. Bai, T. Tait; arXiv:1208.4361

# Isospin Violating DM

Feng et al.; arXiv:1102.4331



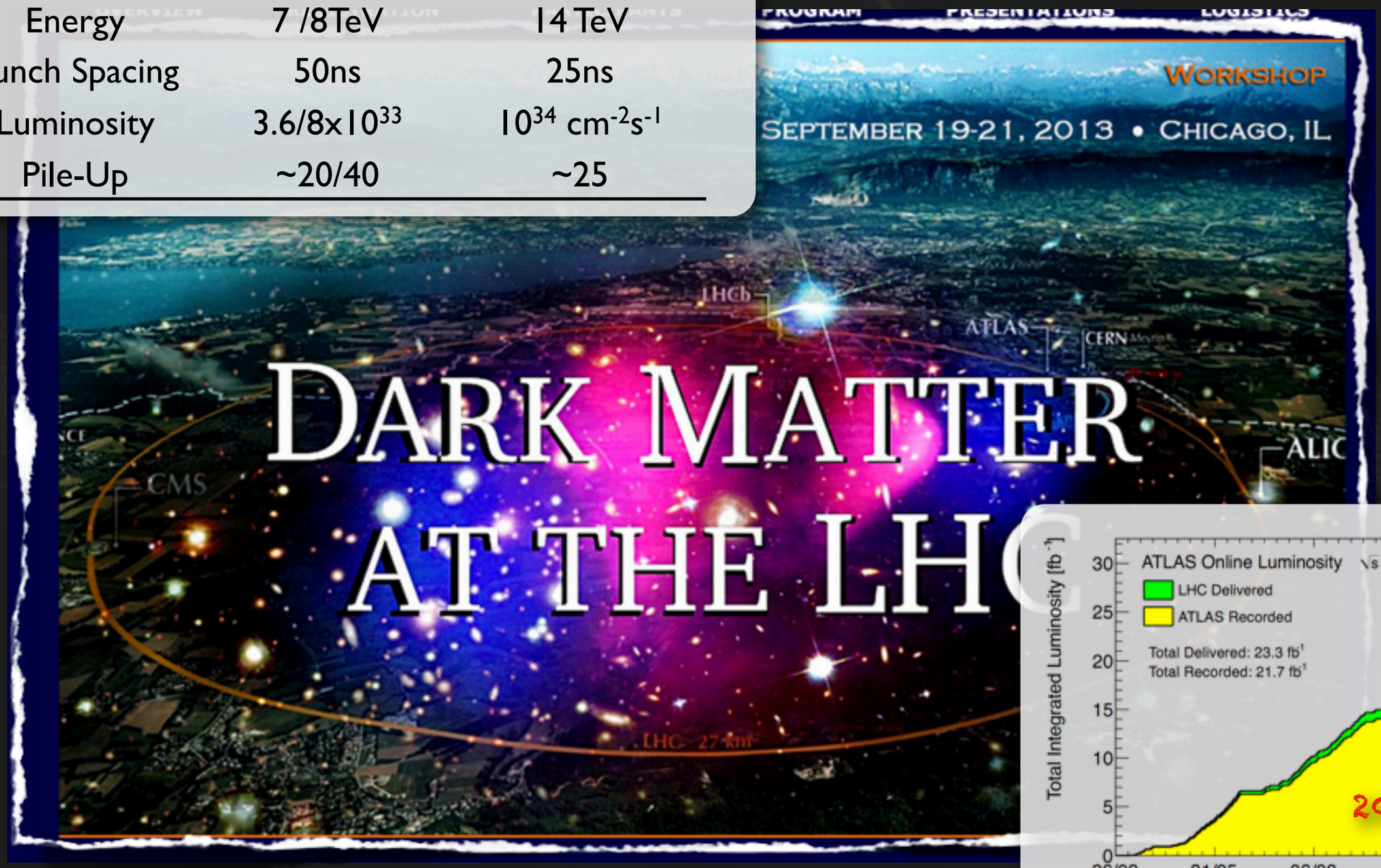


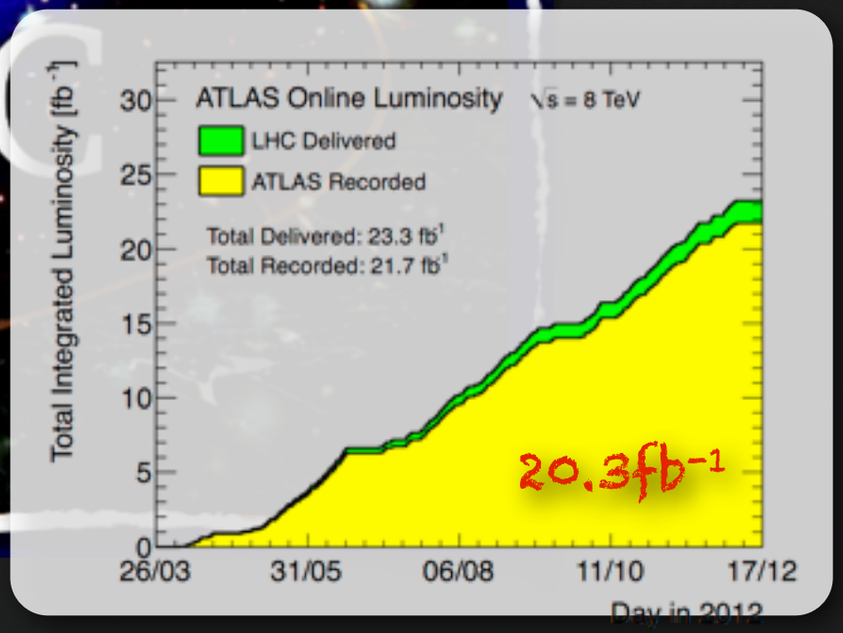



- $f_n/f_p$ = ratio of proton/neutron coupling
- For $-0.72 < f_n/f_p < -0.66$ the DAMA- and CoGeNT-favored regions overlap and the sensitivity of XENON is sufficiently reduced to be consistent with these signals

# Dataset

| | 2011/12 | Design |
|---|---|---|
| Energy | 7 /8TeV | 14 TeV |
| Bunch Spacing | 50ns | 25ns |
| Luminosity | $3.6/8 \times 10^{33}$ | $10^{34}$ $cm^{-2}s^{-1}$ |
| Pile-Up | ~20/40 | ~25 |




**Analysis uses full 2012 ATLAS data set (20.3fb-1)**

# Wimp Signal

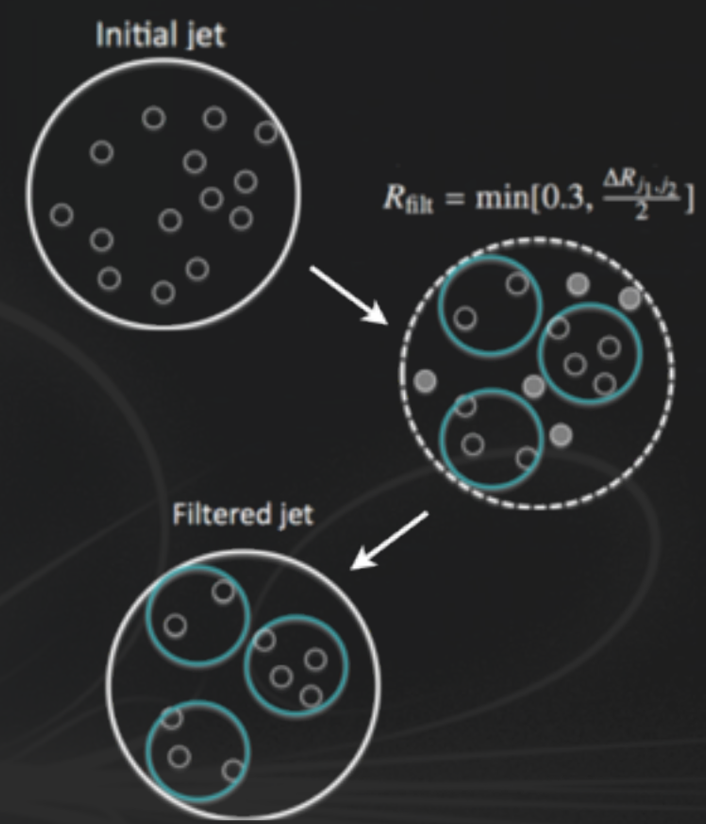
- Using Effective Field Theory
- C1, D1 (scalar), D5 (destructive), D52 (vector) (constructive, mono-W only) and D9 (tensor)with M*=1TeV
- $m_{DM}$ = 1, 50, 100, 200, 400, 700, 1000, 1300
- Sensitive possibly as well to e.g.: H→inv decays (Wh, Zh)

| Coupling Group | Operator | Operator Structure | Coefficient |
|---|---|---|---|
| Scalar quark | D1 | $\overline{\chi}\chi\overline{q}q$ | $m_q/M_*^3$ |
| Vector quark | D5 | $\overline{\chi}\gamma^\mu\chi\overline{q}\gamma_\mu q$ | $1/M_*^2$ |
| Tensor quark | D9 | $\overline{\chi}\sigma^{\mu\nu}\chi\overline{q}\sigma_{\mu\nu}q$ | $1/M_*^2$ |

| Coupling Group | Operator | Operator Structure | Coefficient |
|---|---|---|---|
| Scalar quark | C1 | $\chi^\dagger\chi\overline{q}q$ | $m_q/M_*^2$ |

# Selection

- **Jets boosted**, reconstructed as single large radius jet
- Using '**Cambridge-Aachen**' algorithm for jet reconstruction
  - $p_T$>250 GeV, |η|<1.2
  - 50 GeV < $M_{jets}$< 120 GeV
  - √(y)<0.4, where √(y)<min($p_T^1$, $p_T^2$) ΔR1,2 / $M_{jets}$ (balancing of two leading subjets)

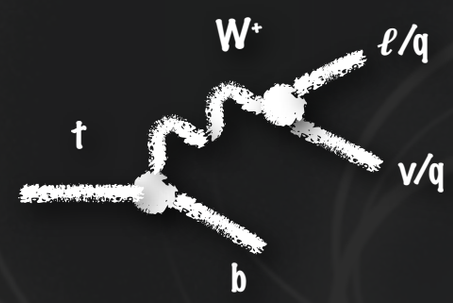


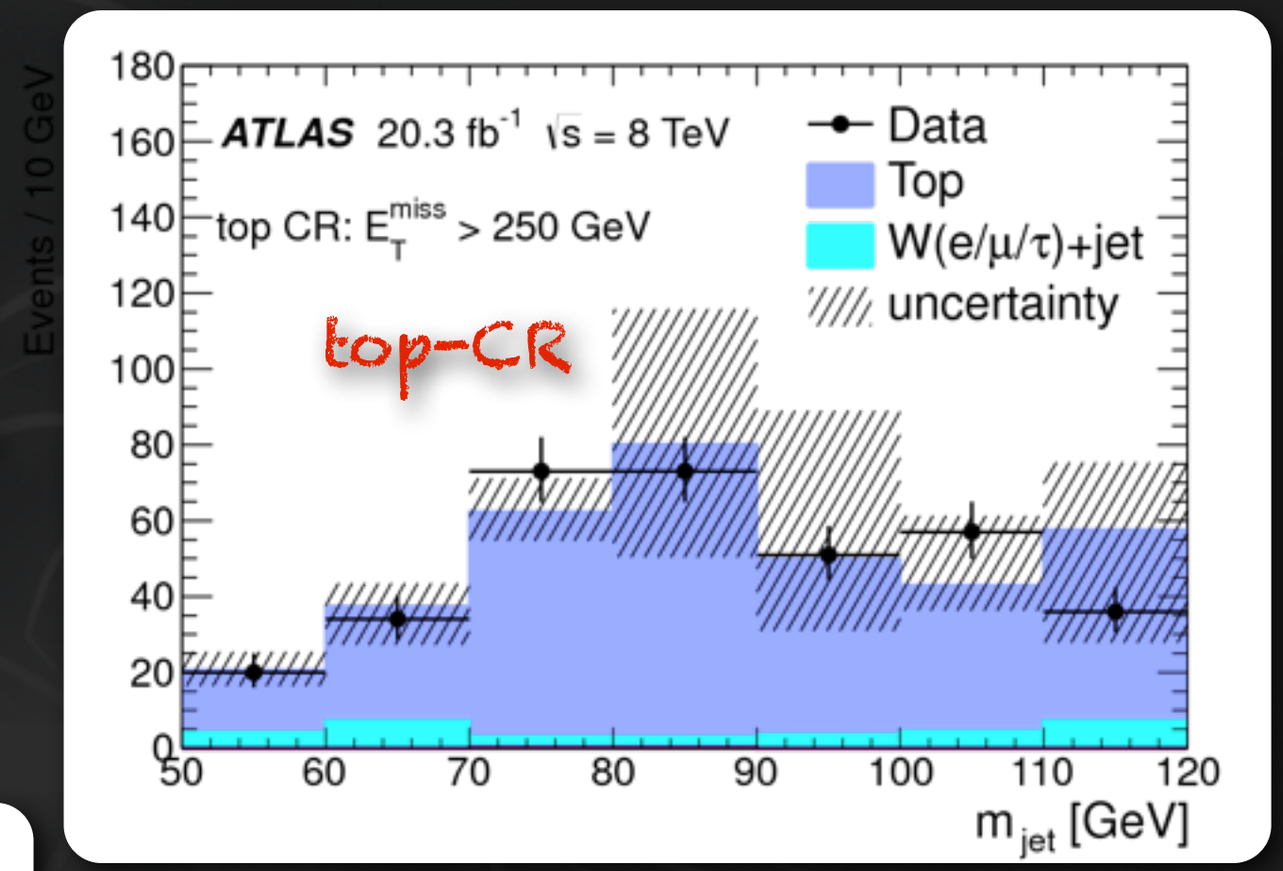


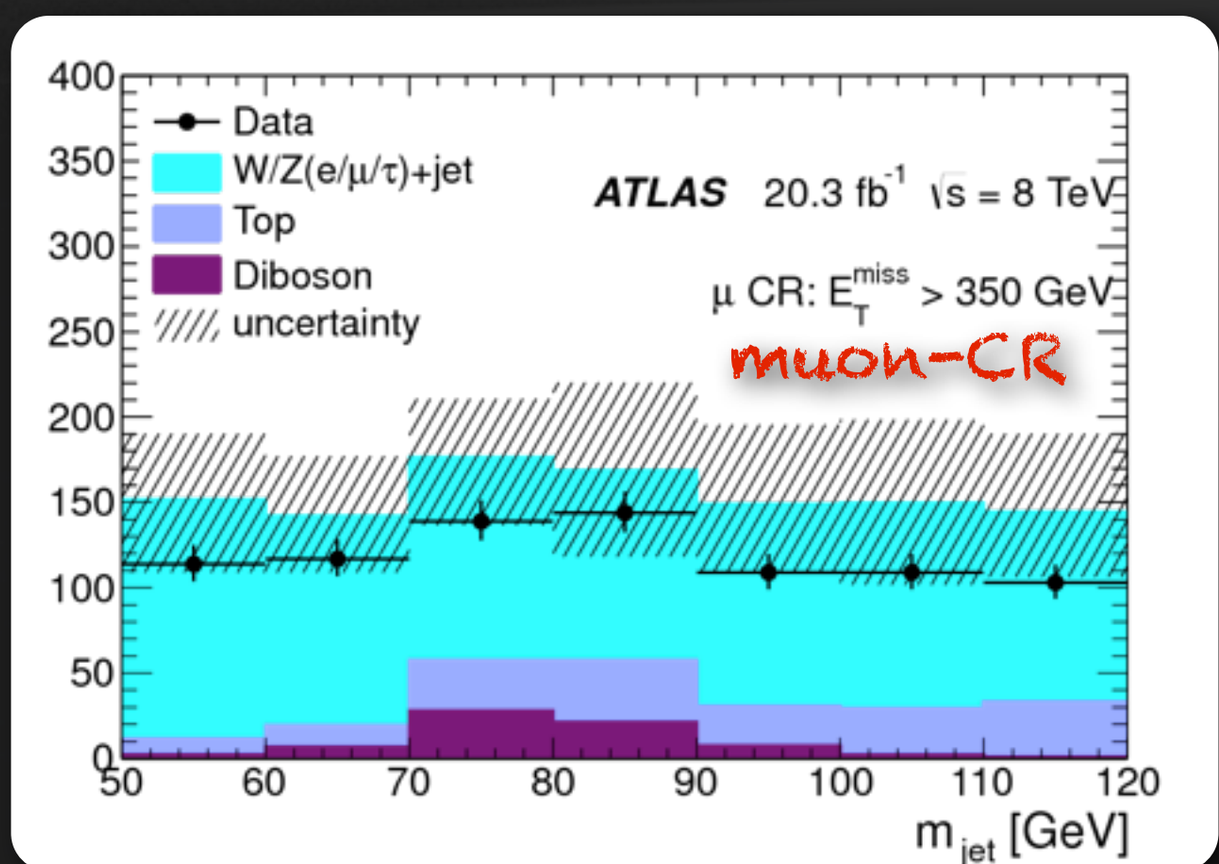
- **Further selections**:
  - <=1 anti-$k_T$ 0.4 jet with $p_T$>40, |η|<4.5
  - separated from large radius jet and $E_T^{miss}$
  - Signal Regions: $E_T^{miss}$> 350, 500 GeV

# Background Selection

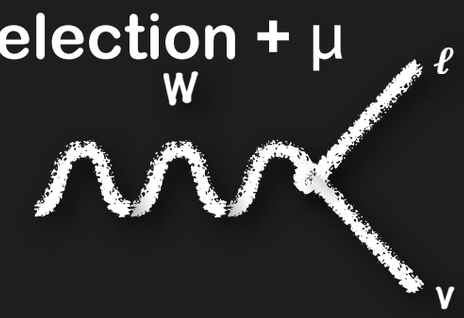
- **MC simulations:**
  - ttbar
  - single top
  - diboson
- **Top-CR region:**
  - 1 b-tag, 2 narrow jet, 1 large jet



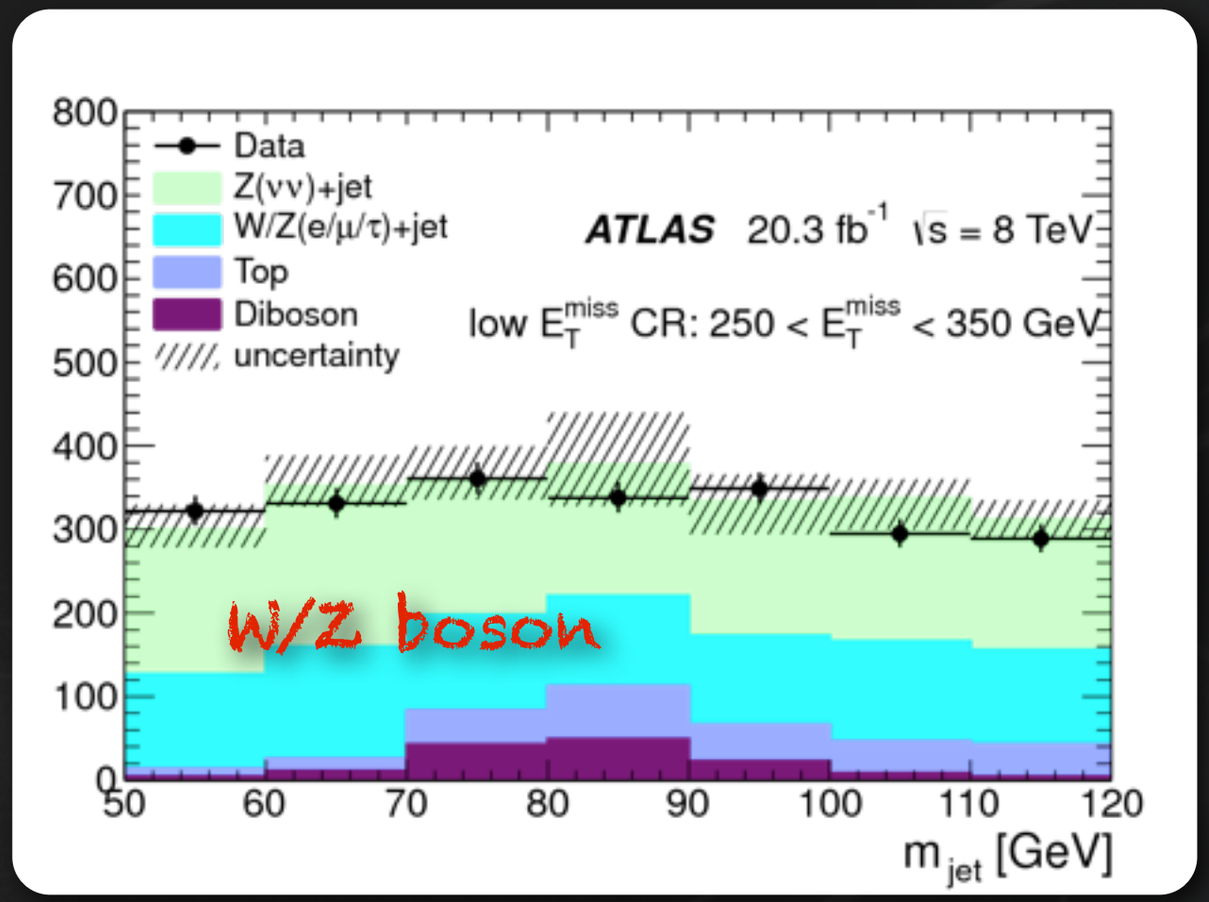



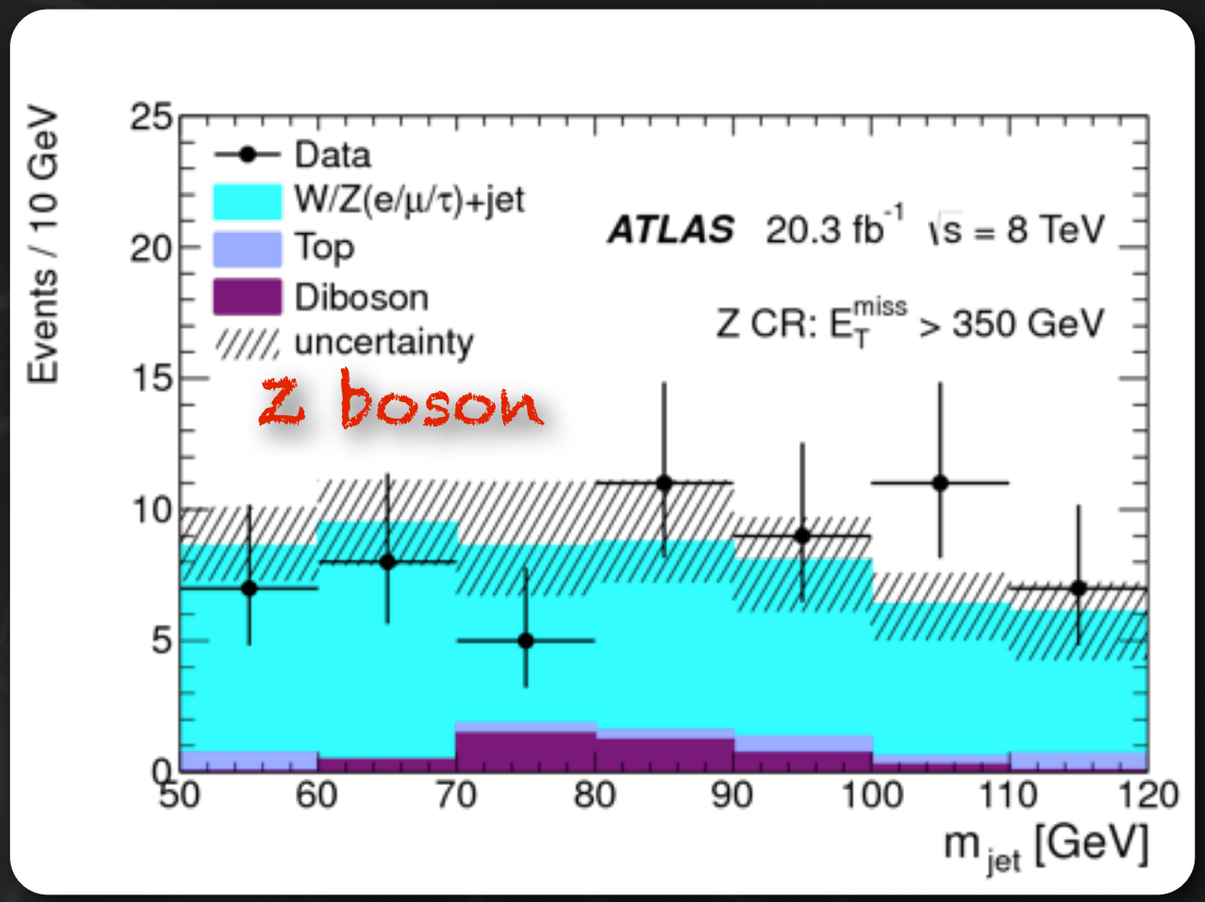




- **Dominant bkgd:**
  Z(νν)+jets, W(lν)+jets and Z(ll)+jets
- **Data-driven method**
  - muon: signal selection + μ

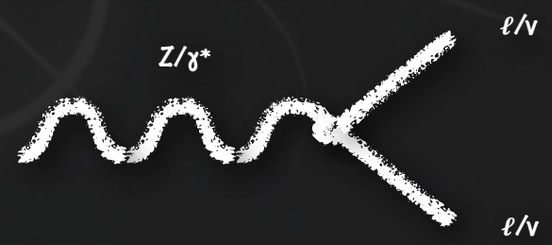


# Control Regions







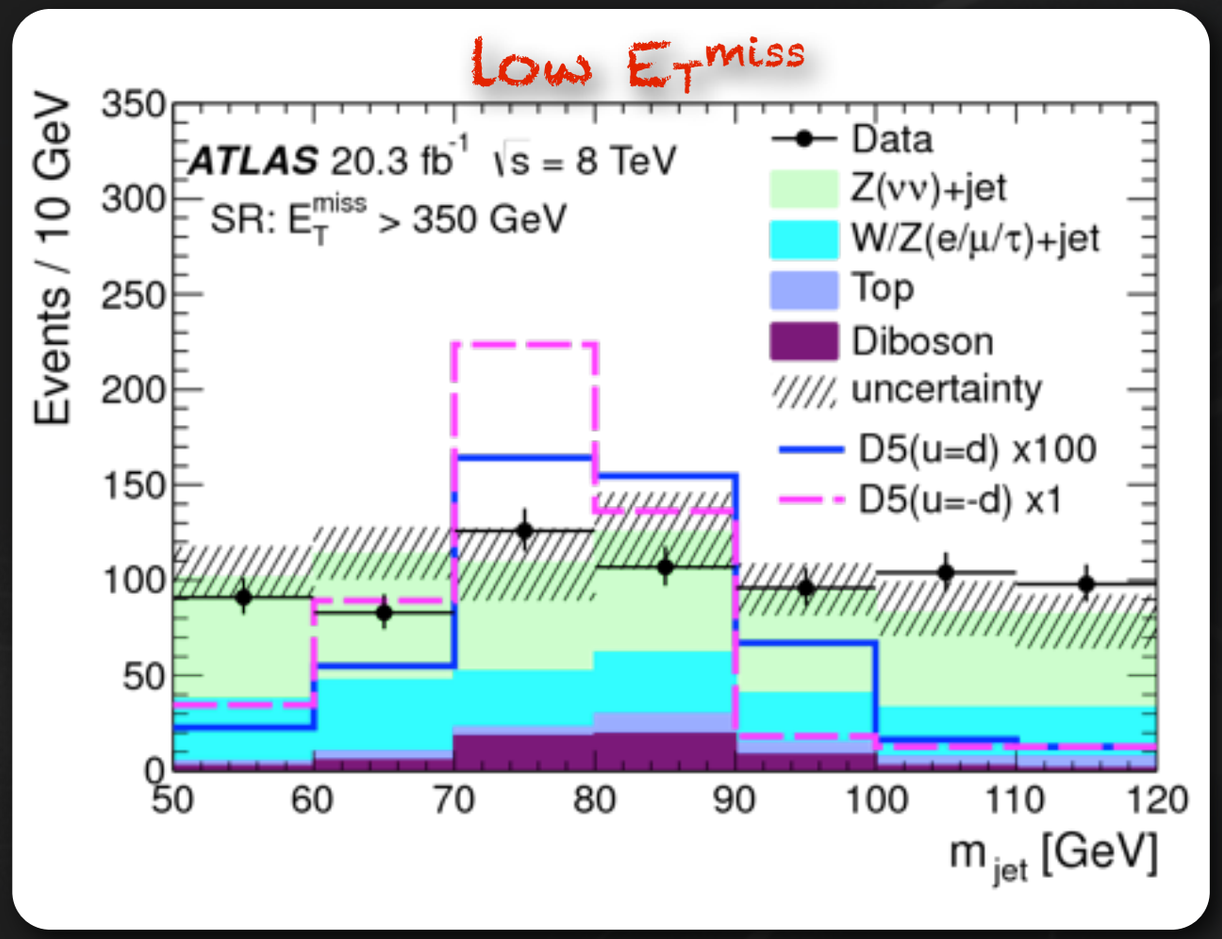

- **W-CR: 250 < $E_T^{miss}$ < 350 GeV**
- **Z-CR: 2μ, $E_T^{miss}$ > 350 GeV**
- **Good agreement in all validation regions**

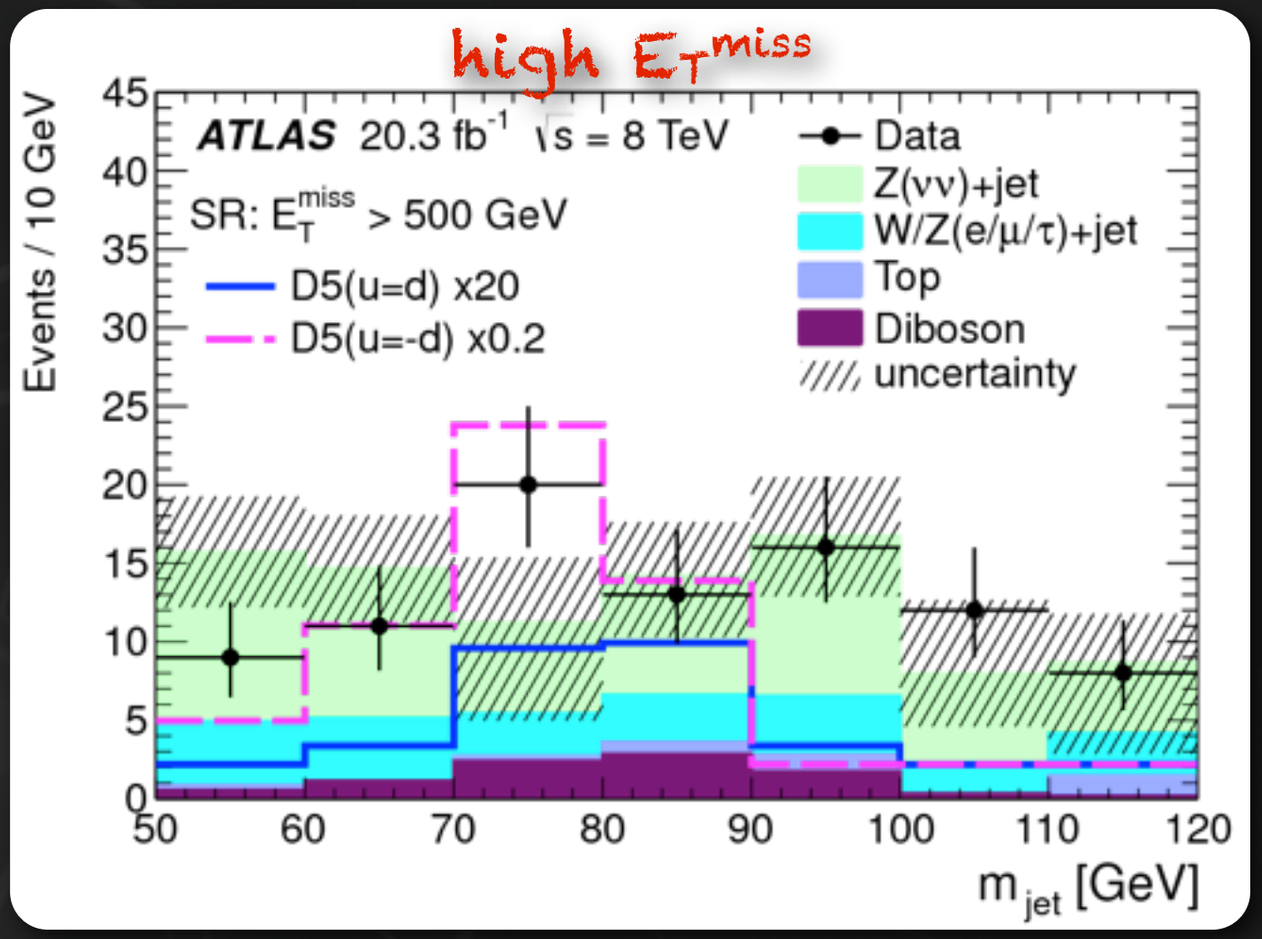
# Event yield

| Process | $E_T^{miss} > 350$ GeV | $E_T^{miss} > 500$ GeV |
|---|---|---|
| $Z \to \nu\bar{\nu}$ | $400^{+39}_{-34}$ | $54^{+8}_{-10}$ |
| $W \to \ell^{\pm}\nu, Z \to \ell^{\pm}\ell^{\mp}$ | $210^{+20}_{-18}$ | $22^{+4}_{-5}$ |
| $WW, WZ, ZZ$ | $57^{+11}_{-8}$ | $9.1^{+1.3}_{-1.1}$ |
| $t\bar{t}$, single $t$ | $39^{+10}_{-4}$ | $3.7^{+1.7}_{-1.3}$ |
| Total | $710^{+48}_{-38}$ | $89^{+9}_{-12}$ |
| Data | 705 | 89 |

- W/Z+jets dominant (85%)
  - QCD negligible in hadronic W/Z selection
- Uncertainties dominated by limited CR statistics

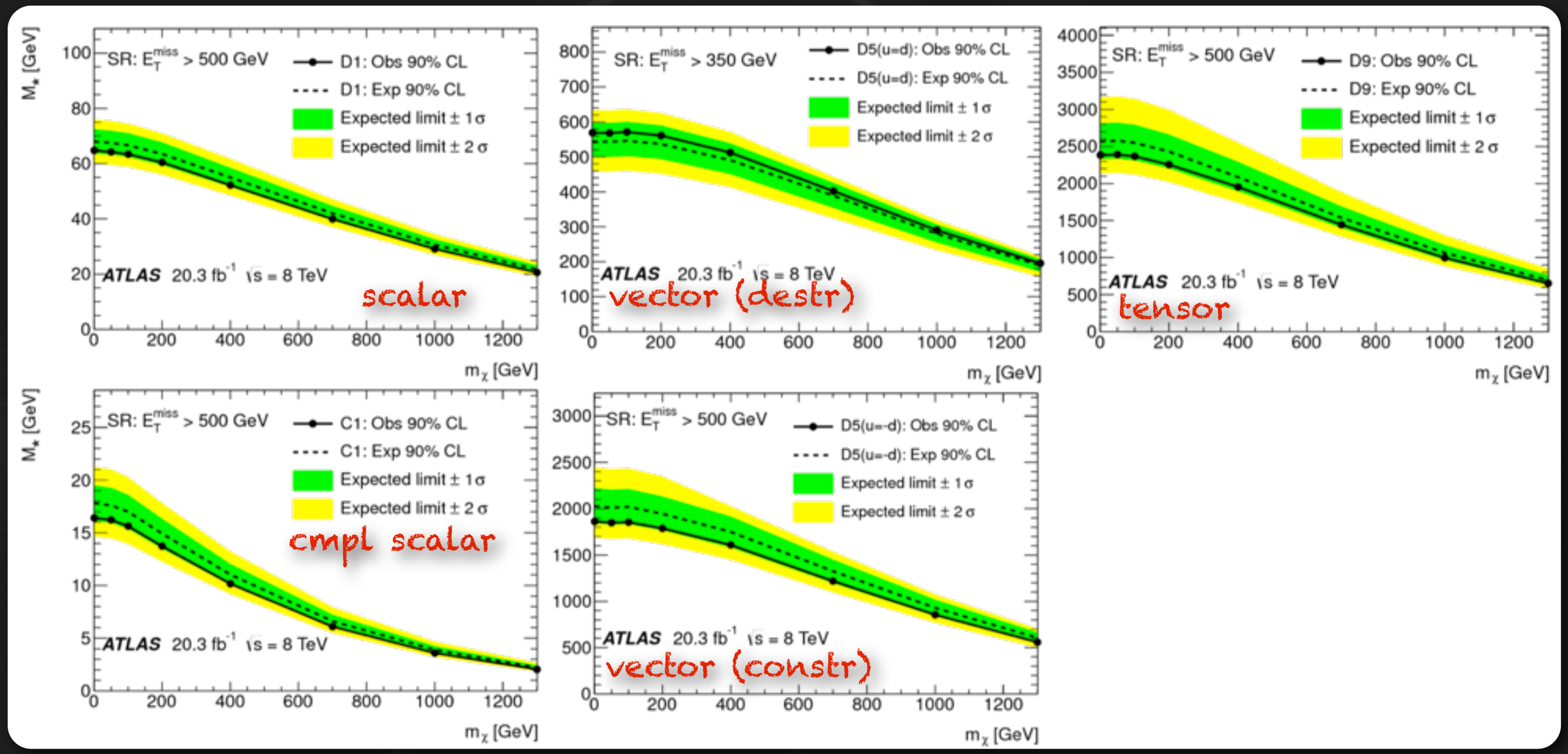
# Results



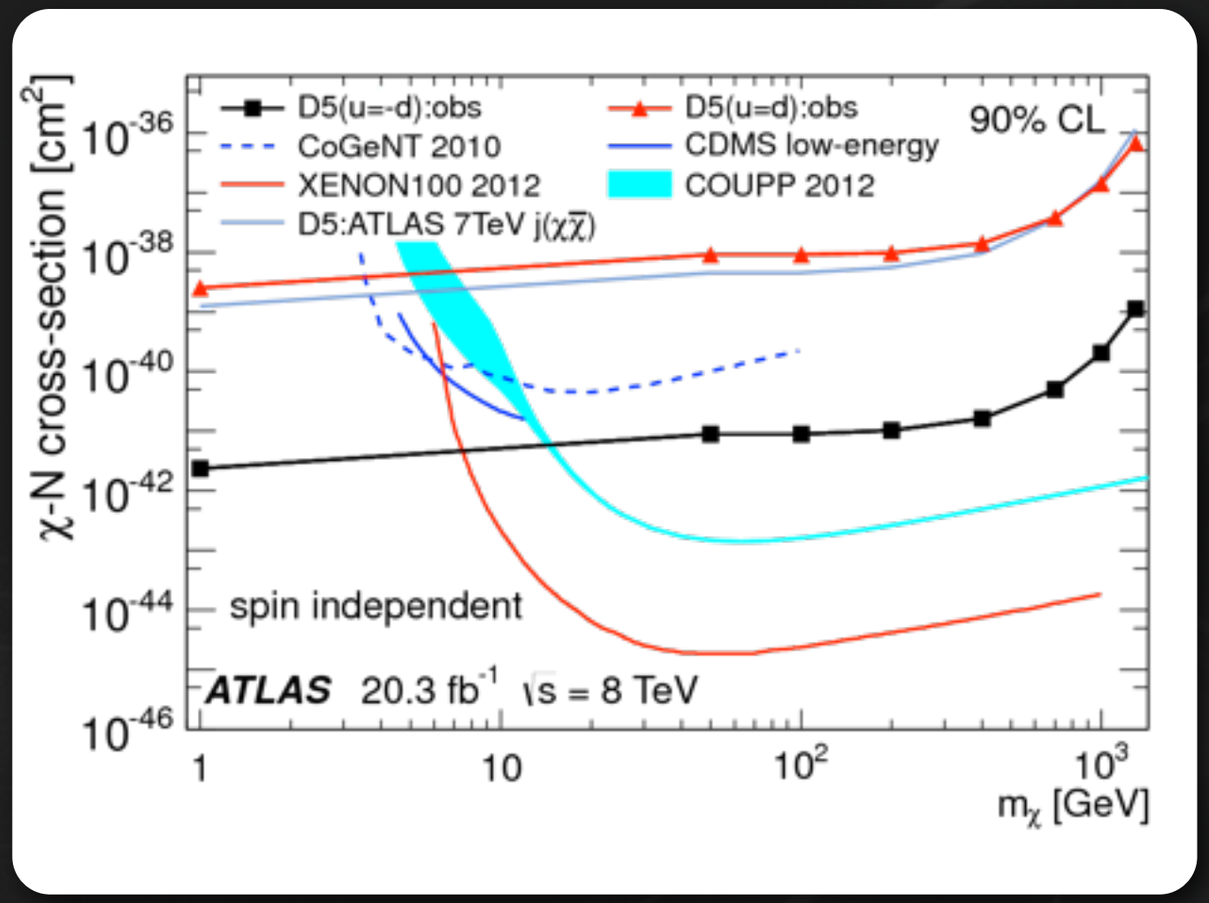

Unfortunately no excess over SM found

# Limits on Mediator

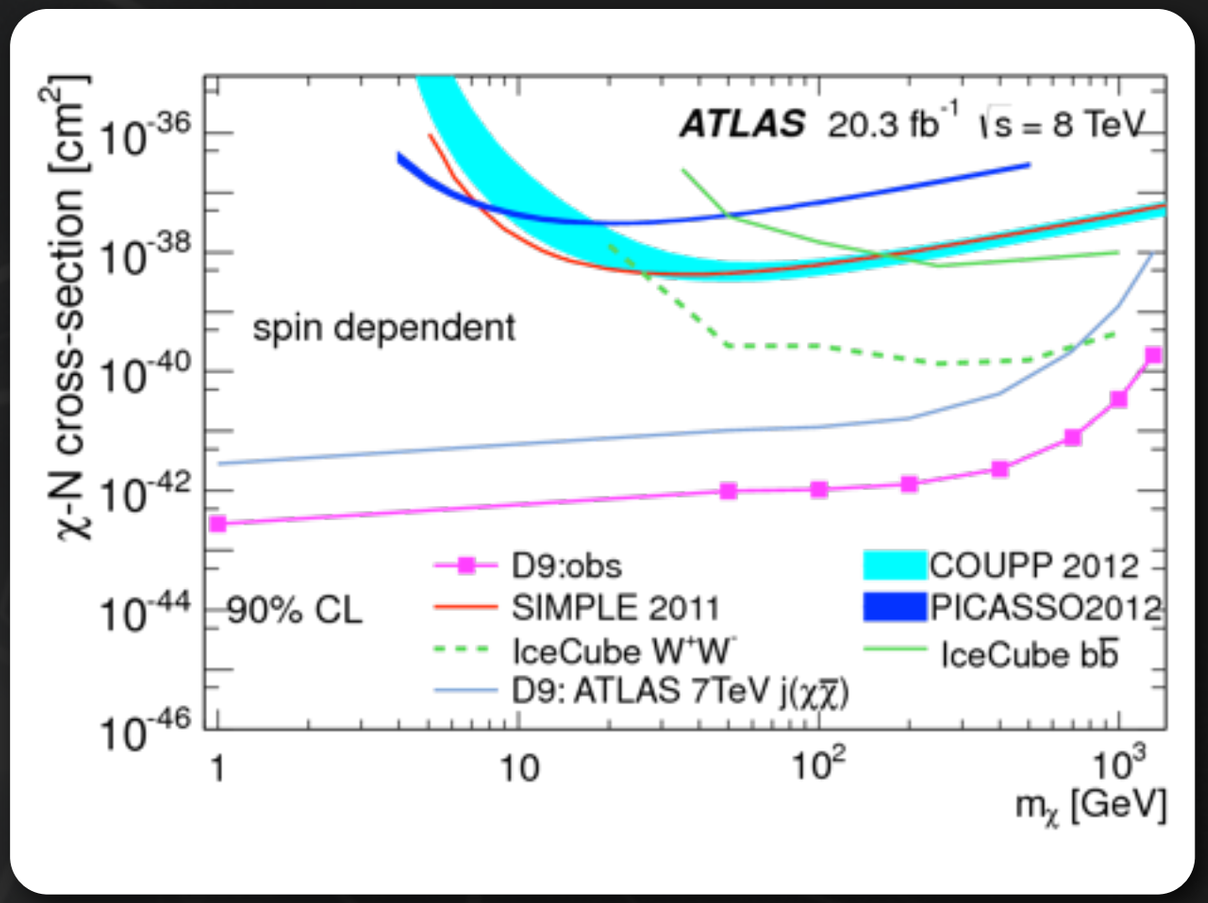



Individual limits on **Mediator Mass**

# Limits on WIMP-Nucleon xsec



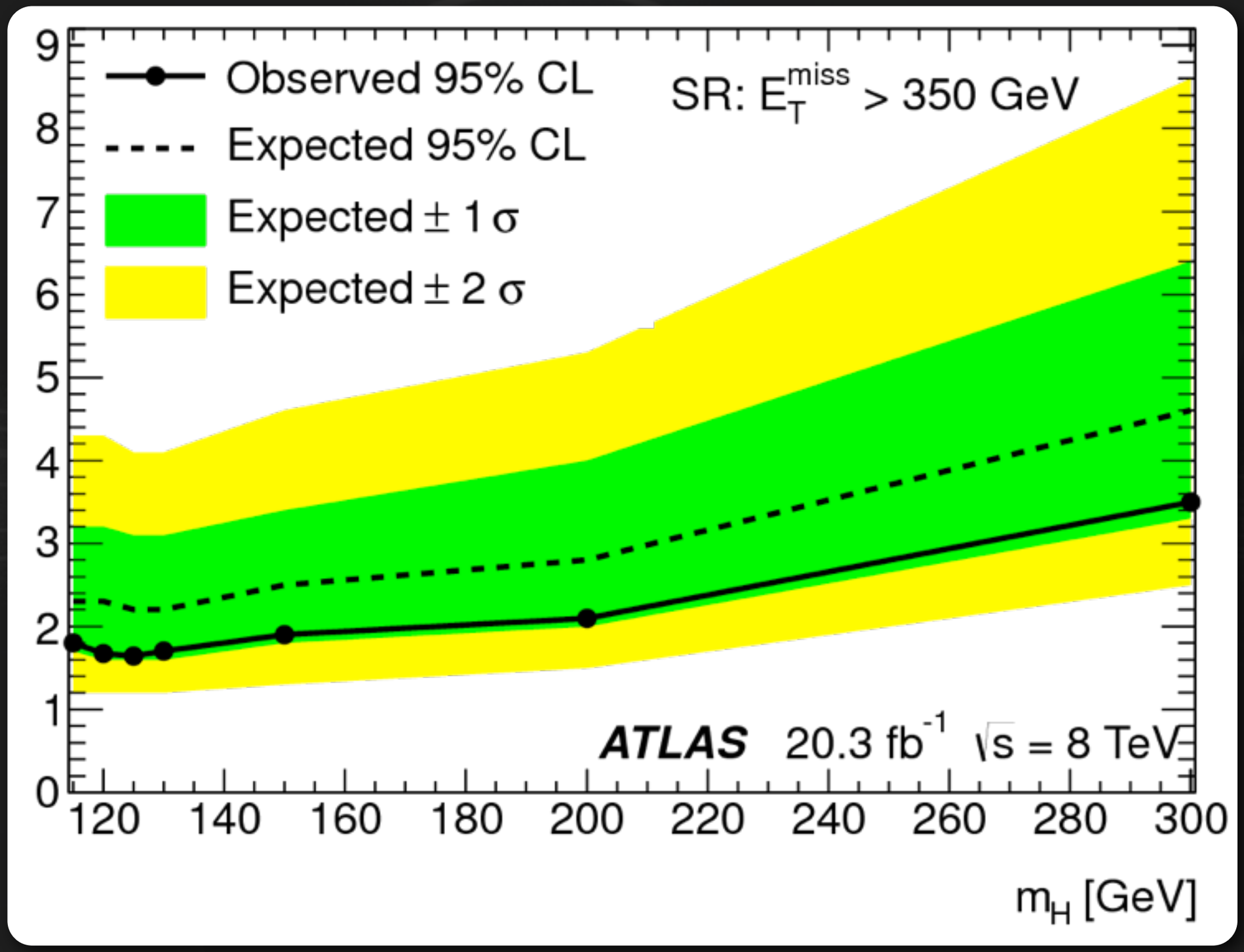

spin-independent




spin-dependent

- Converting into **limits on WIMP-Nucleon** scattering cross section
- Spin independent **limits improve by three orders of magnitude** if up/down have opposite sign

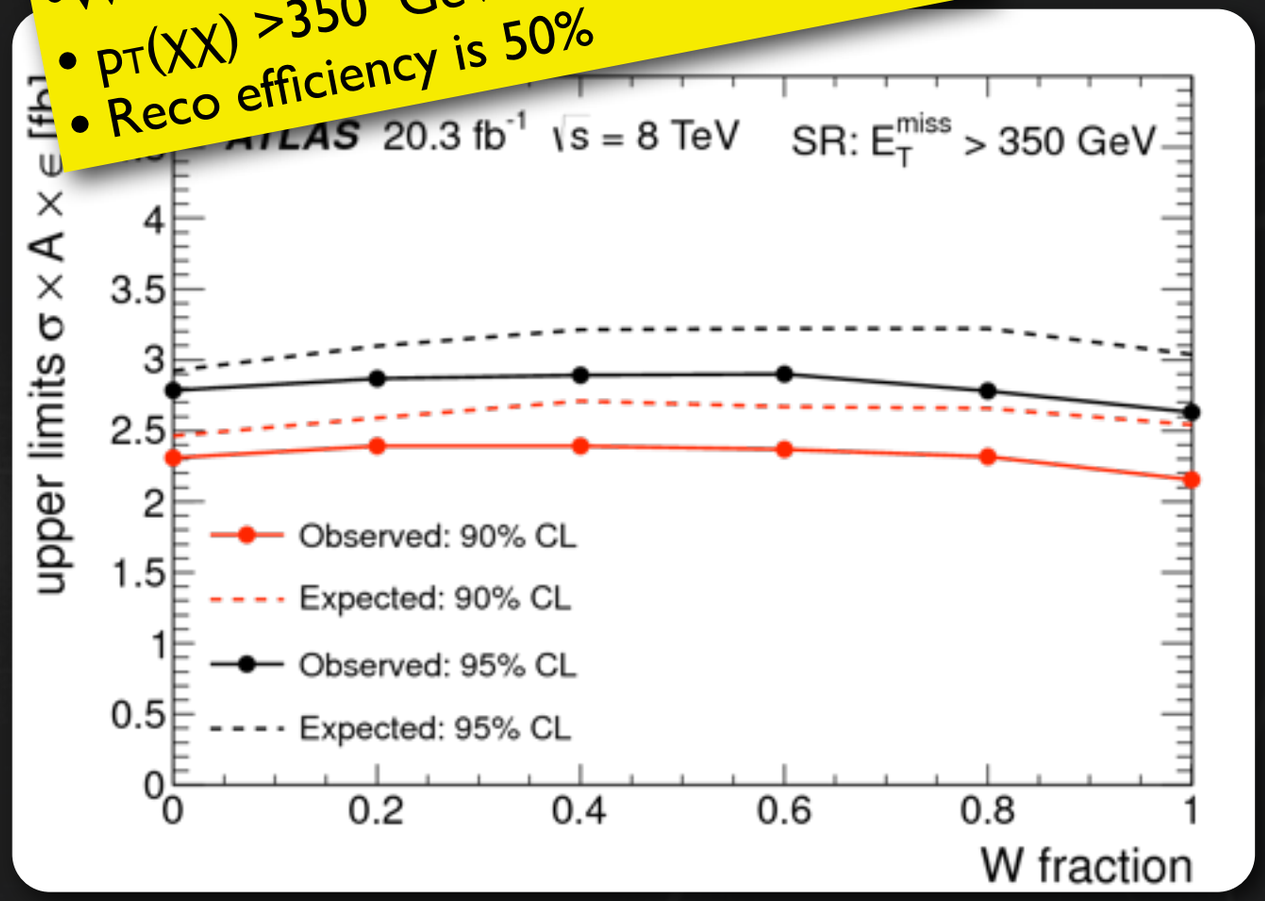
# Limits on H→inv.

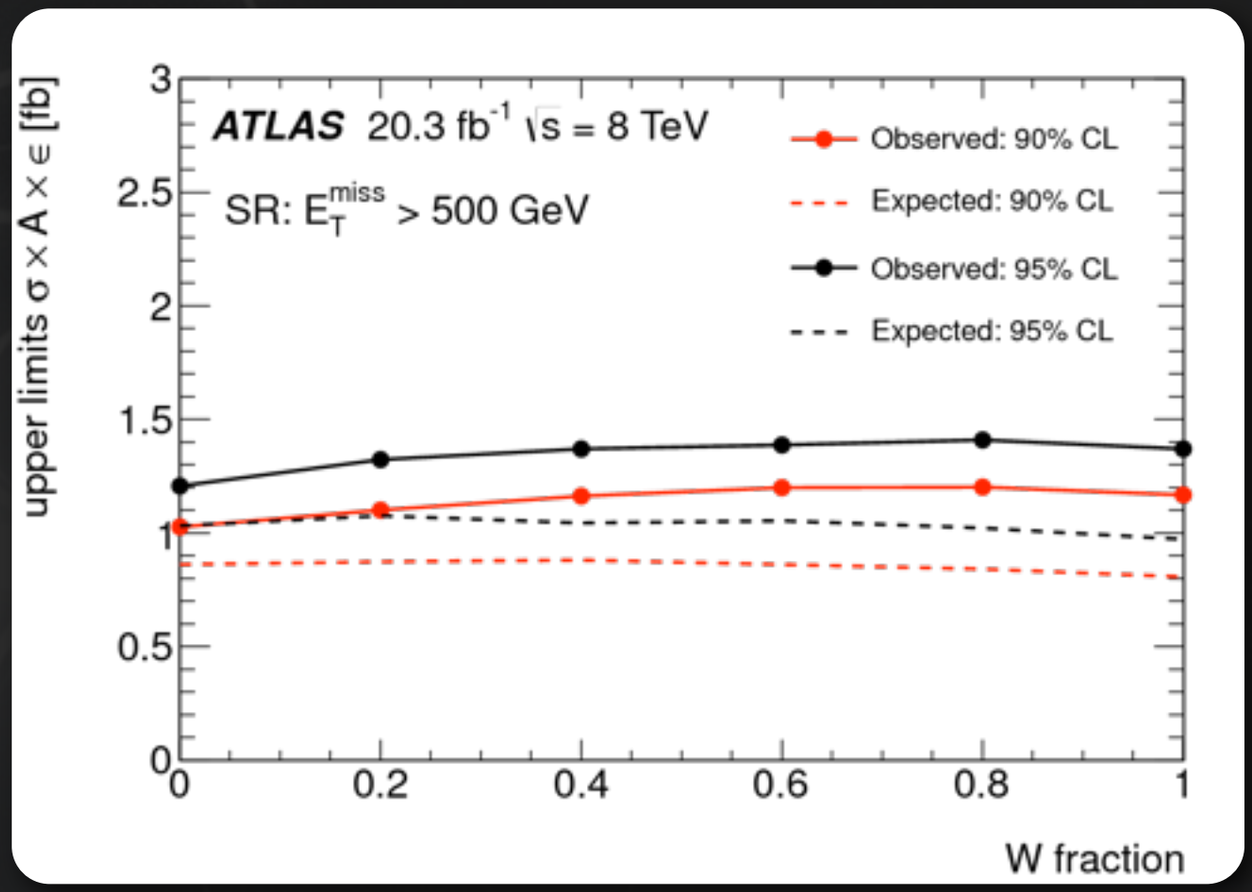



Limits on Higgs→inv

# Model independent limits

Fiducial regions:
- W or Z $p_T$>250GeV, |eta|<1.2, $\sqrt{y}$ > 0.4
- $p_T$(XX) >350 GeV or 500 GeV
- Reco efficiency is 50%



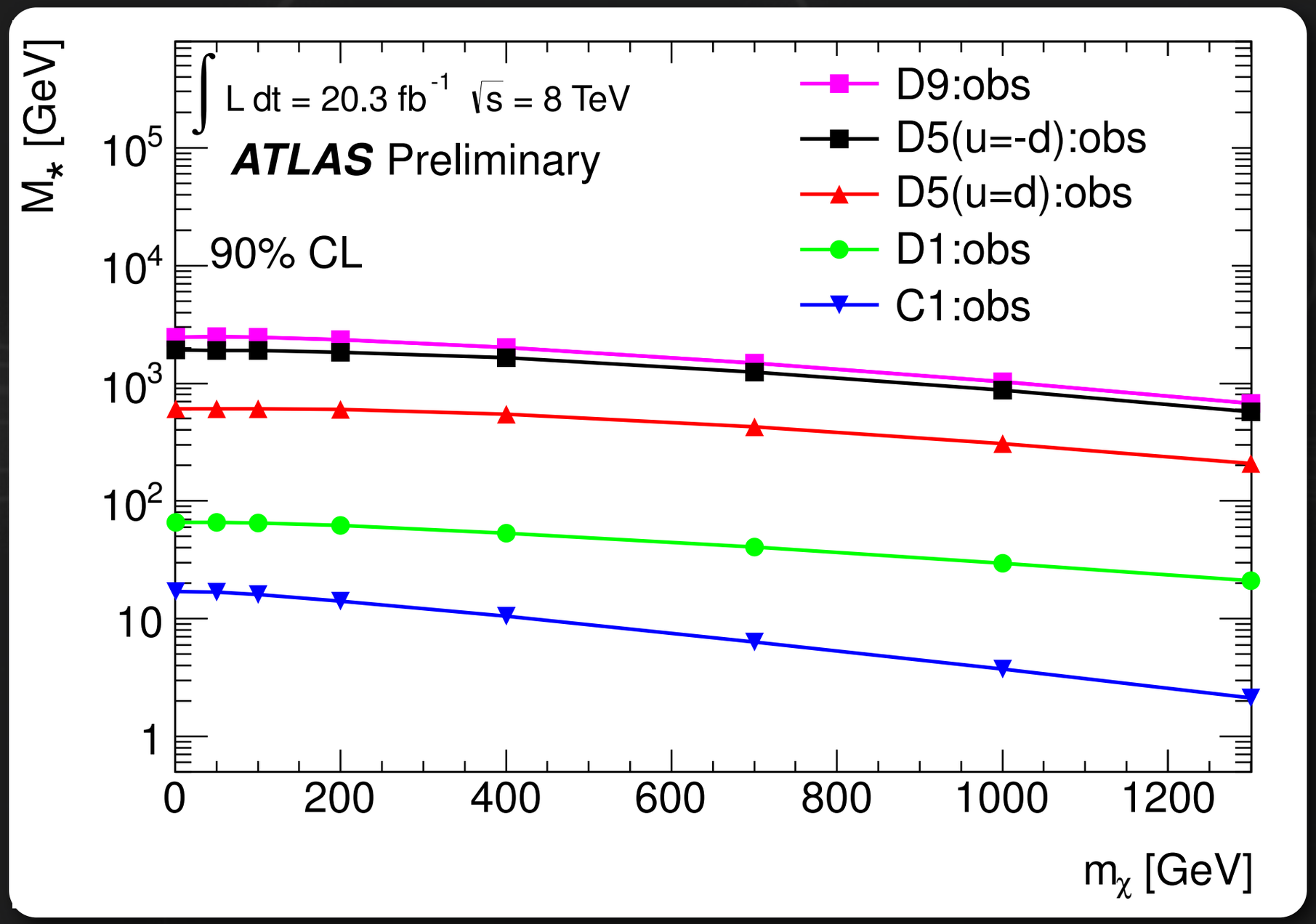




**Model independent limits** as function of W-boson fraction

# Conclusion

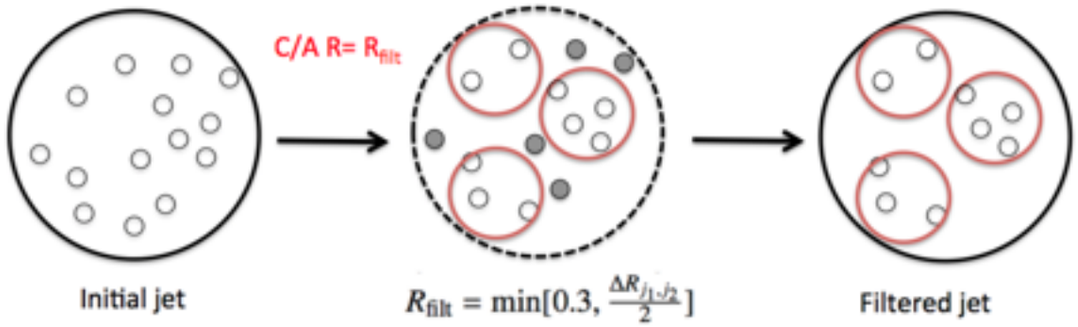
- First WIMP search using 'mono-W/Z'
- In case of constructive interference between up- and down quarks, the results set the strongest limits on M*
- There is no significant excess observed in these signal regions.
- Exclusion limits are extracted on mono-W and mono-Z signals.
- Please see ATLAS-CONF-2013-073 for details

# Backup


$\int$ L dt = 20.3 fb$^{-1}$ $\sqrt{s}$ = 8 TeV
ATLAS Preliminary
90% CL
D9:obs
D5(u=-d):obs
D5(u=d):obs
D1:obs
C1:obs
M$_*$ [GeV]
$10^5$
$10^4$
$10^3$
$10^2$
10
1
0
200
400
600
800
1000
1200
m$_\chi$ [GeV]

# C/A Jets

- For highly boosted objects objects, decay products have narrow dR distribution
- To recover efficiency & resolution:
  - Use a single large R Cambridge/Aachen jet encompassing all decay products
  - Revert last step of clustering and look for two low mass, symmetric sub-jets
  - Recluster constituents of sub-jets, keep 3 hardest new sub-jets
- Process greatly improves jet mass measurement, QCD separation




arXiv:1306.4945