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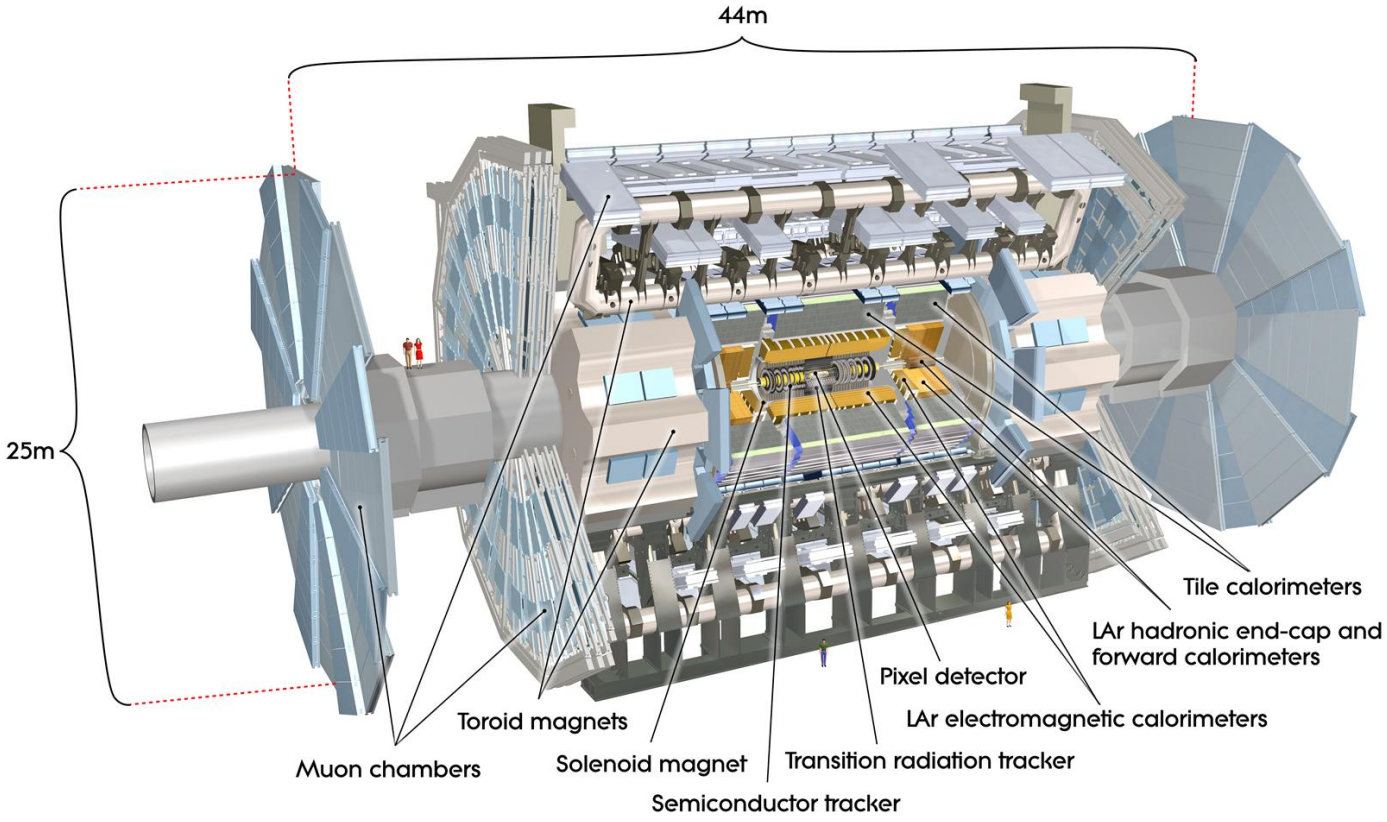
# Searches for Physics Beyond the Standard Model

*in Monojet Final States with ATLAS*

Spåtind 2016

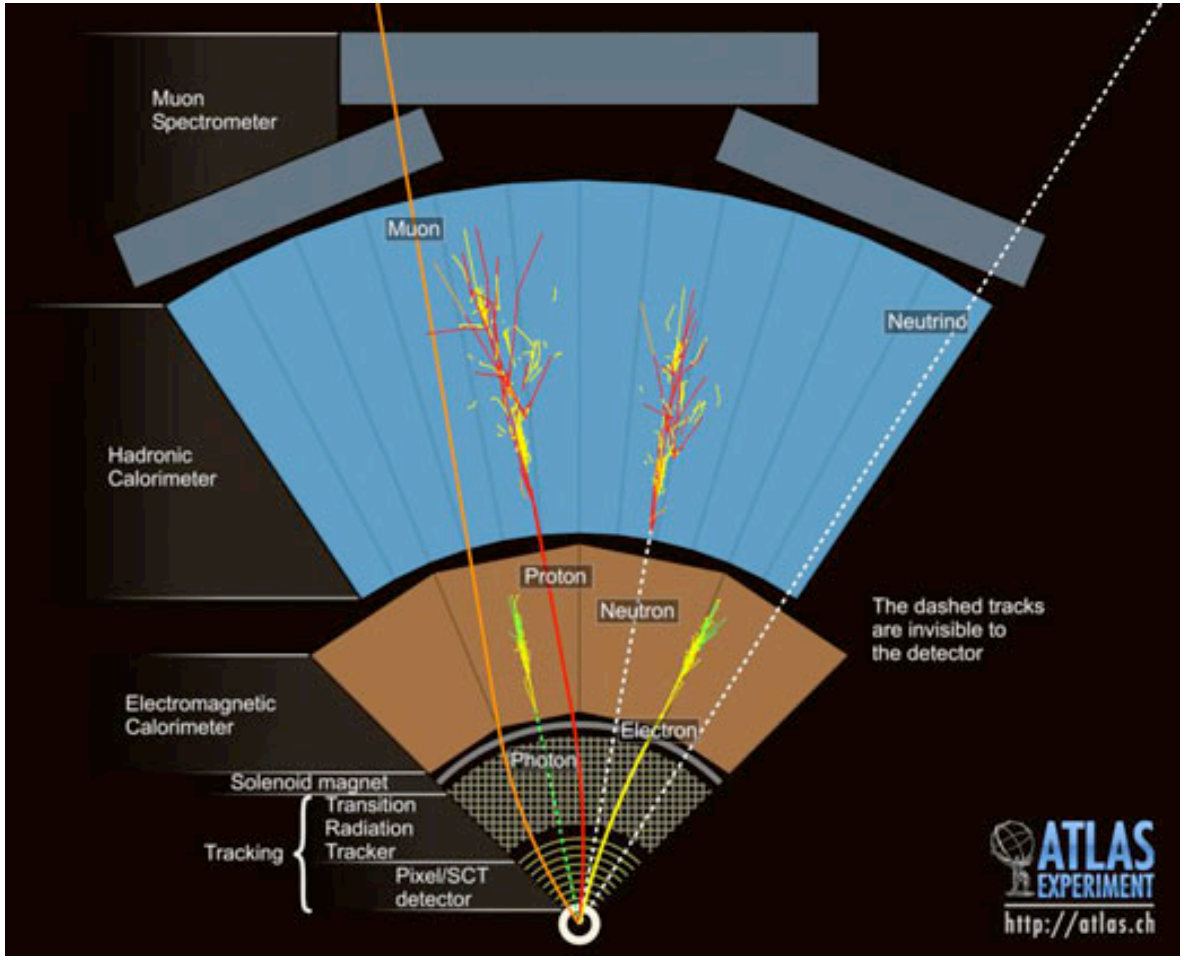
*Olof Lundberg*

# The ATLAS detector




Trackers, calorimeters, several muon detectors in order to detect e, μ, τ, γ and hadronic jets originating in partons. Designed to examine 40 million events per second. A sophisticated 3-level trigger system, 100kHz trigger rate at L1 → O(100) events per second saved for analysis.

# The ATLAS detector




Particles shower and/or leave tracks in different parts of the detector

Momenta and energies measured through bending of tracks and calorimeter deposits

Hermeticity of the detector used to infer information about "invisible" particles

# Monojet Analysis

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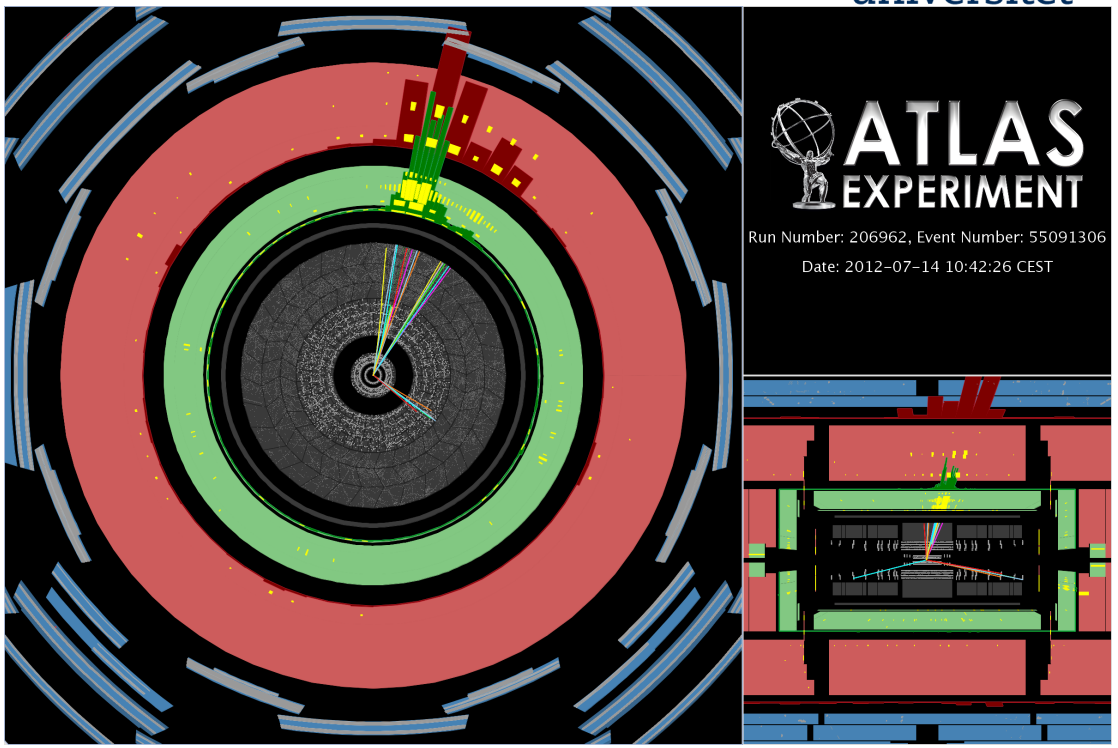
Monojet Event: Highly energetic jet in association with missing transverse energy: $E_T^{miss}$. Momentum is carried by "invisible" particles.

Predicted in many models for BSM physics




Monojet event display:Leading jet $p_T$ 852 GeV, MET 863 GeV

# The Stockholm group

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Stockholm monojet group:

G. Bertoli (Ph.D), C. Clement (senior), O. Lundberg (Ph.D) ,

V. Rossetti (Post-doc)

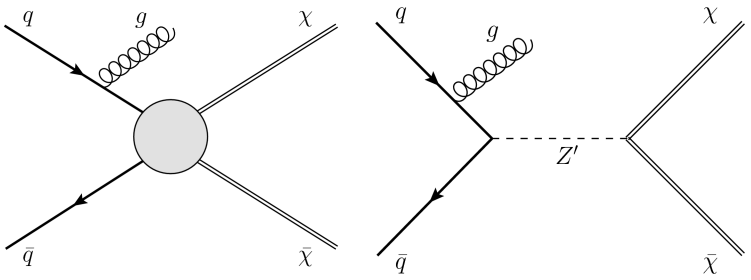
8 TeV paper: Eur.Phys. J. C (2015) 75:299. SU contribution to data analysis, calculation of backgrounds and studies of systematics,  ADD extra dimension limit calculations.

***Topic of today's talk***

13 TeV analysis: Strong SU contribution, now also including SUSY interpretation.

# Models with monojets

***WIMP Dark Matter*** pair production with ISR jets. Analyzed in EFT framework and as simplified models



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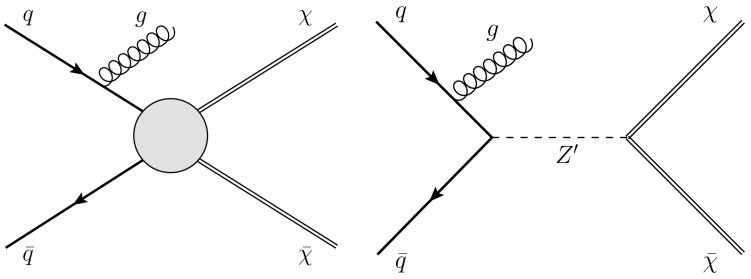
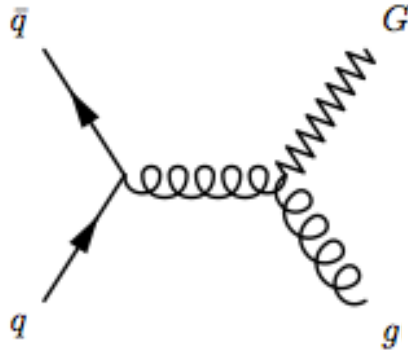



Graviton production in ***ADD model*** with *n* extra dimensions and reduced Planck Scale $M_D$ (TeV-scale gravity)



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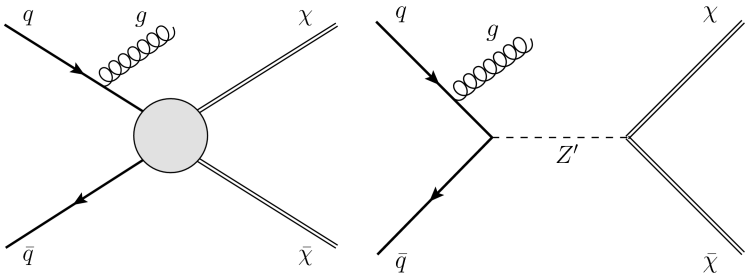


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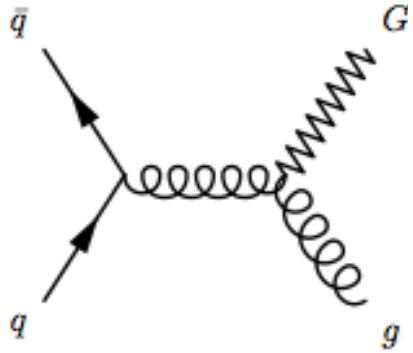
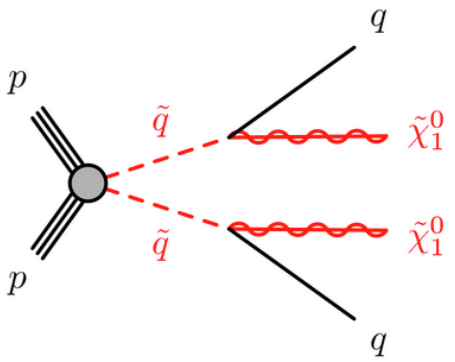



***Supersymmetry*** with small squark-neutralino mass gap (Run 2). Standard collider SUSY searches lack sensitivity



# Event Selection (Run 1)

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**Selection criteria**

- Leading jet must be central ($|\eta| < 2.0$), and $p_T > 120$ GeV
- Veto on events with leptons (e, μ) and/or isolated tracks (to suppress τ)
- Plus additional criteria that ensures "monojet topology", with $E_T^{miss}$ back-to-back with jet
- Nine different Signal Regions with $E_T^{miss}$ cut from 150 to 700 GeV
- Calculate limits on new physics from the Signal Region with highest sensitivity, for each particular model

**Main backgrounds**: Z→νν + jets(irreducible), W→lν + jets

Computed using 5 dedicated Control Regions with ***lepton veto reversed*** to enrich in W/Z + jets events.

# Final background estimates

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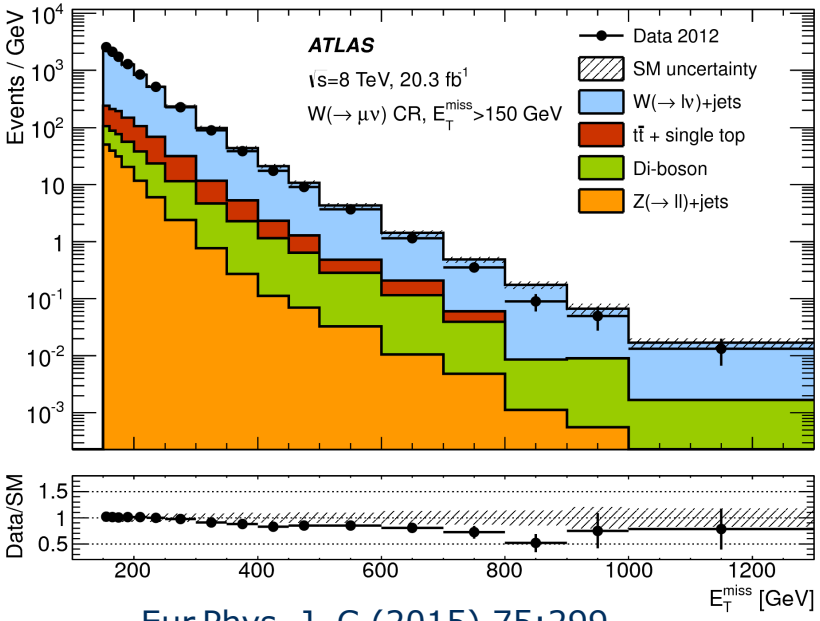
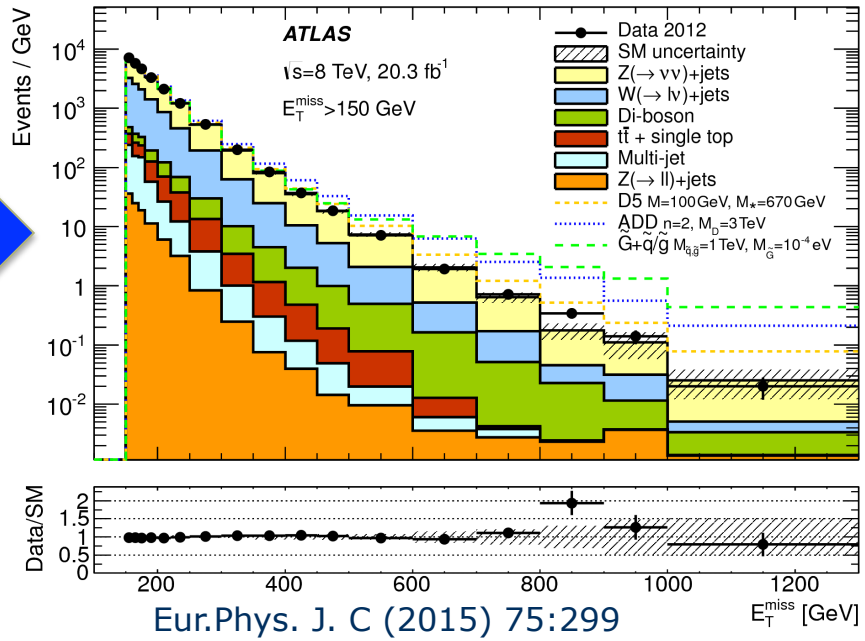
## CONTROL REGION




Eur.Phys. J. C (2015) 75:299

## SIGNAL REGION

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$$N_{Z\nu\nu}^{SR} = (N_{data}^{CR} - N_{NON-W/Z}^{CR}) \times \frac{N_{MC}^{SR}}{N_{MC}^{CR}} \times C_l \times R_{trig}$$

Full 20.3 fb$^{-1}$ data set agrees well with SM expectations. We use this results to set experimental limits on signal models

# Dark Matter Limits

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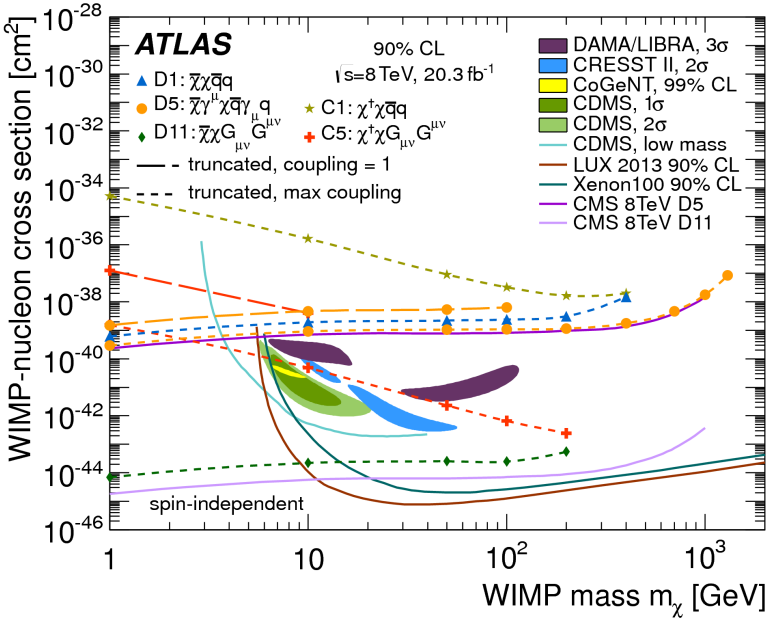


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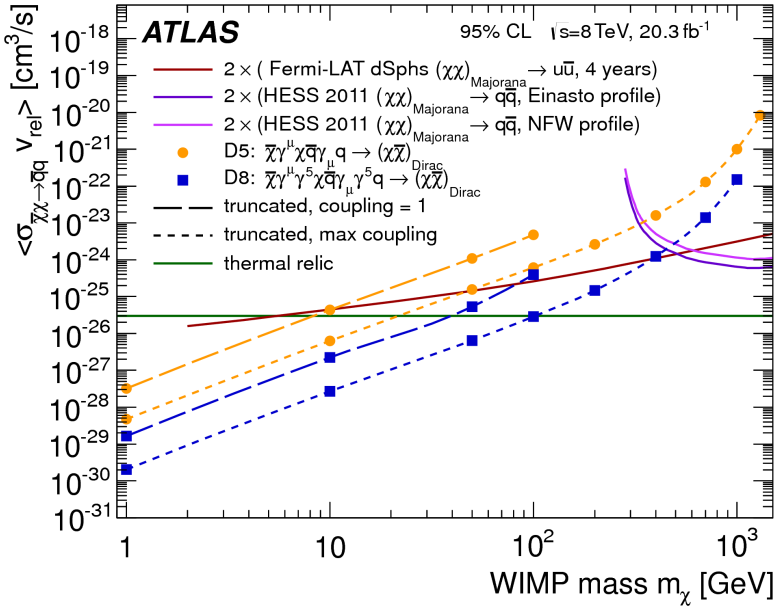
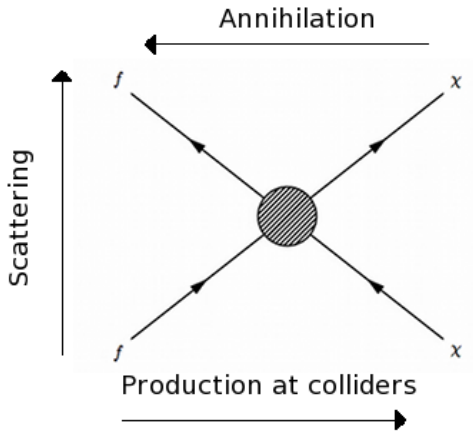
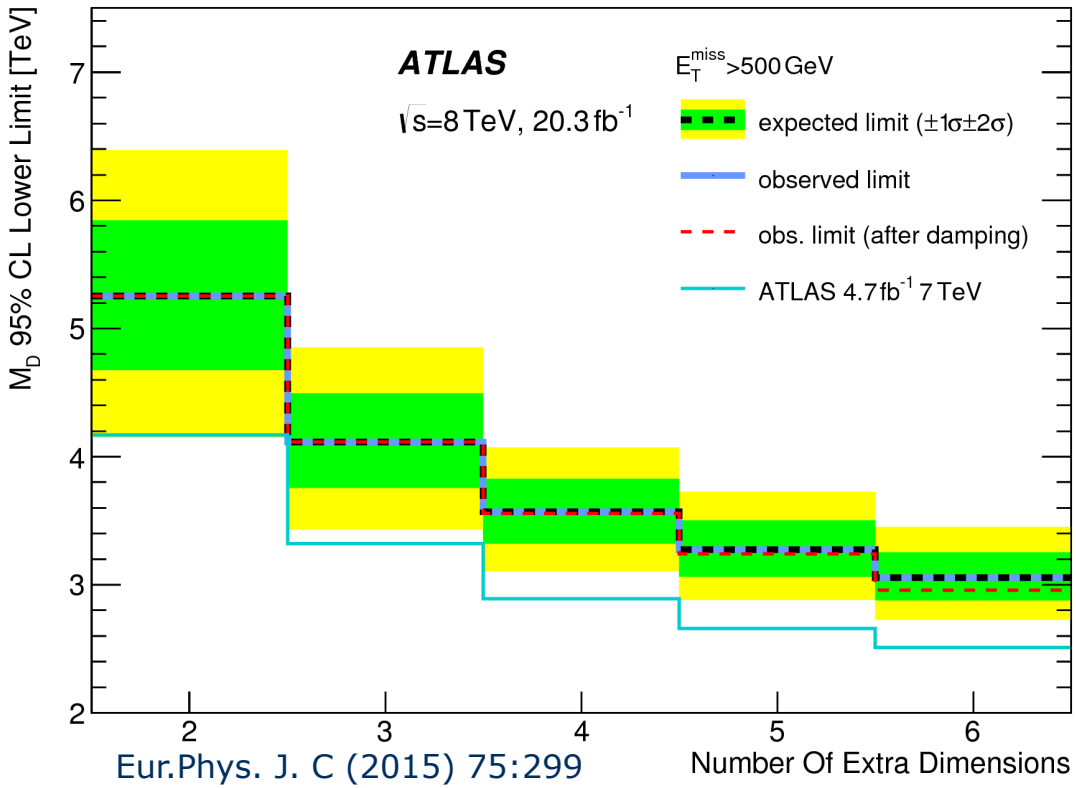



ATLAS limits: Lines with dots. Each color is a given operator, each line style a different assumption for the validity of the effective theory

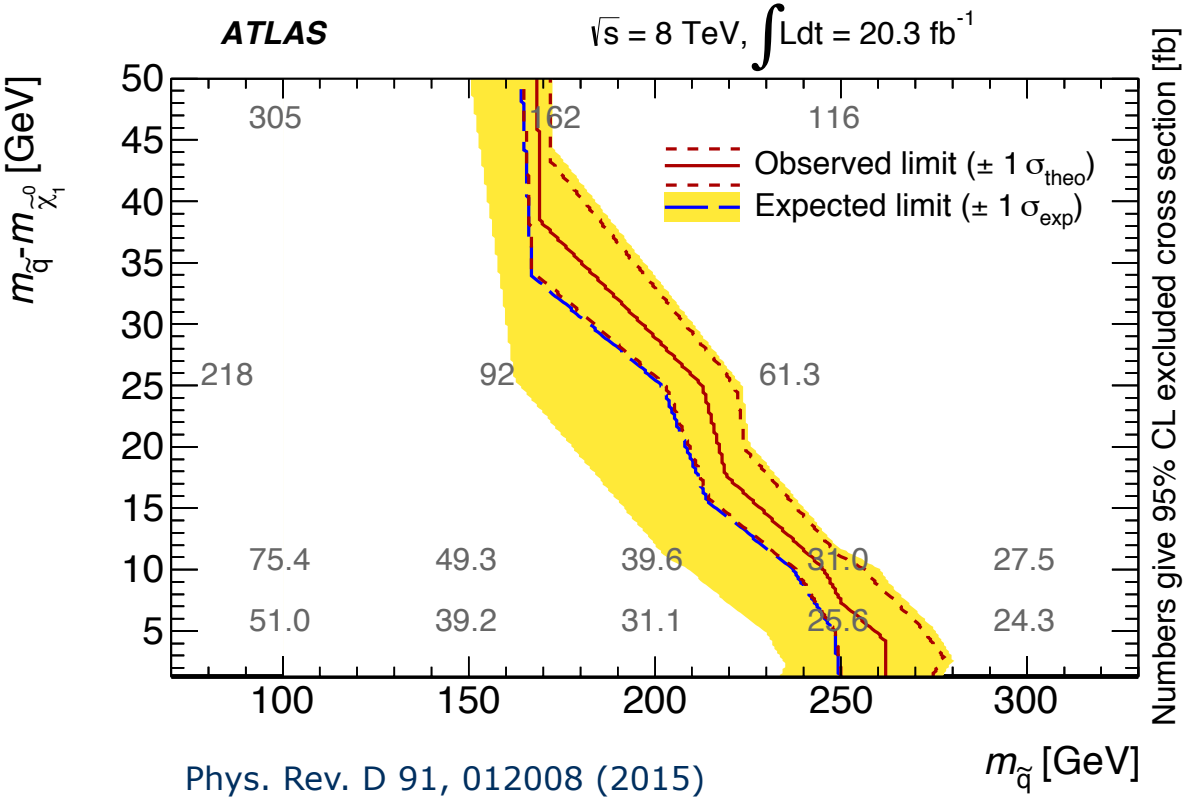


# ADD gravity limits




Limit on reduced Planck Scale $M_D$ for different numbers of extra dimensions, compared to previous ATLAS results.

# Compressed SUSY limits (mono-γ)




Phys. Rev. D 91, 012008 (2015)

Monojet analysis will be used in Run2 for compressed scenarios – in Run1 such models were analyzed with monophotons. Models to the left of red line are excluded.

# Summary

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The monojet analysis provides sensitivity to several models for physics Beyond the Standard Model

Strong Stockholm University contribution to Run 1 as well as Run 2 analysis

With the 20.3 $fb^{-1}$ of collected 8 TeV data from 2012 ATLAS sets limits on scales and WIMP masses in Dark Matter models, as well as on the reduced Planck scale in ADD gravity models

13 TeV analysis ongoing – stay tuned!

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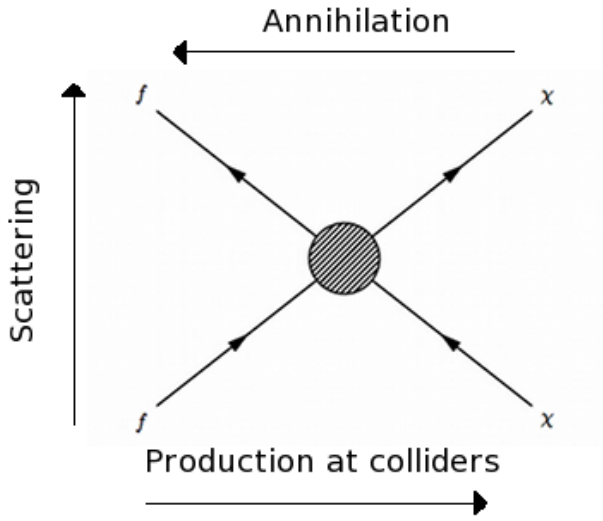
# Backup

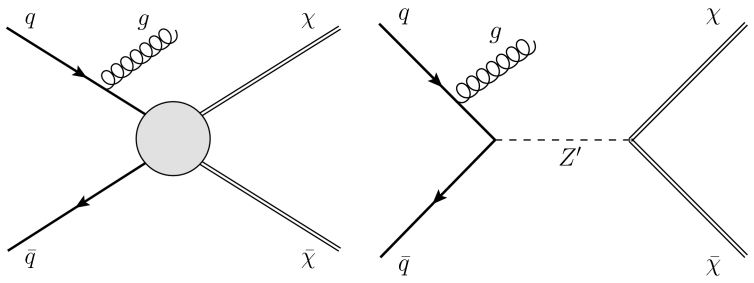
# Dark Matter

26% of energy content of the universe is Dark Matter (DM).

WIMP candidates could be produced at colliders. ISR of gluon or quark gives us a handle: Monojet event!

Analyzed in EFT framework, setting limits on $M_\chi$ and $M_*$ ($\sim M_{med}\sqrt{g_{DM}g_{SM}}$), or simplified models with mediator explicitly included.



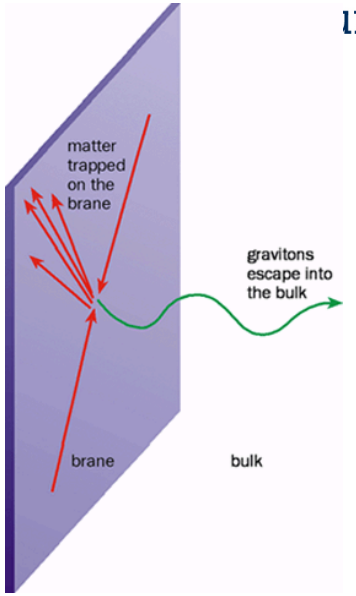



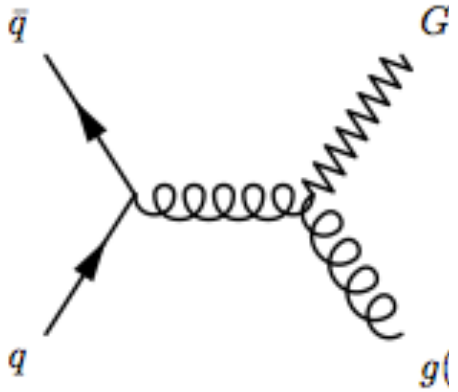
# Gravity in the ADD scenario

Hierarchy problem: Gravity $10^{32}$ times weaker than weak interaction. Why?

Can be solved by introducing new small **extra dimensions** making gravity strong at short distances (***ADD*** model). New

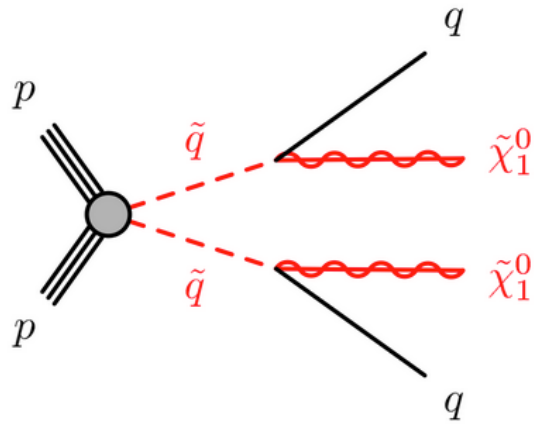
Predicted parton + "invisible" graviton final state: Monojet event!



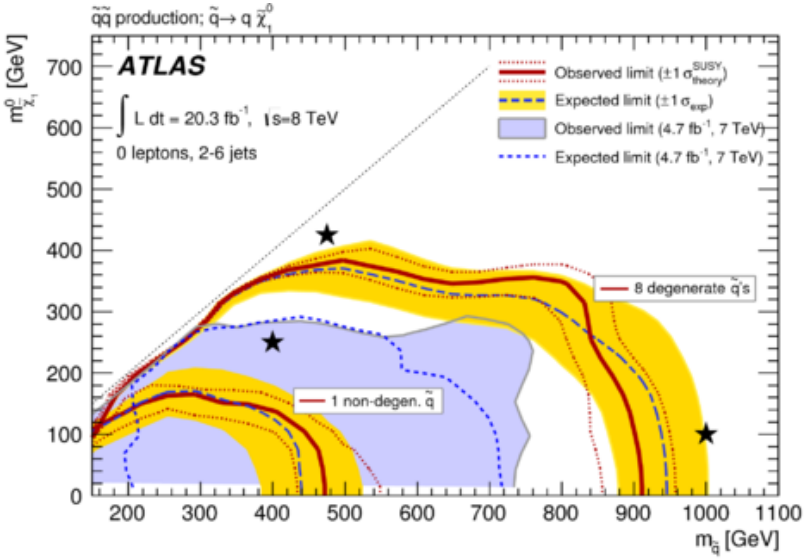
# Supersymmetry: Compressed

Supersymmetry: Solves the hierarchy problem with new set of superparticles. Also handily provides DM candidate.



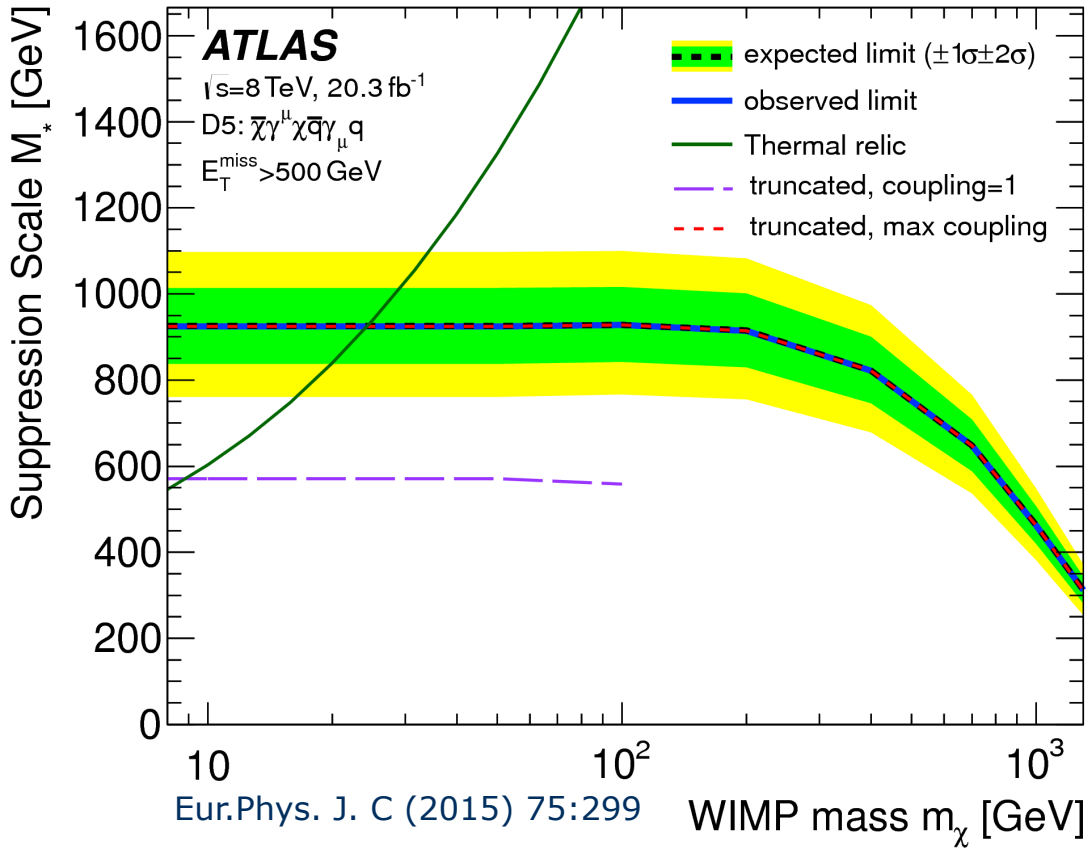

Standard collider SUSY searches with multi-jets misses region with small squark-neutralino mass gap

ISR-tagged events (Monojet) provide sensitivity.



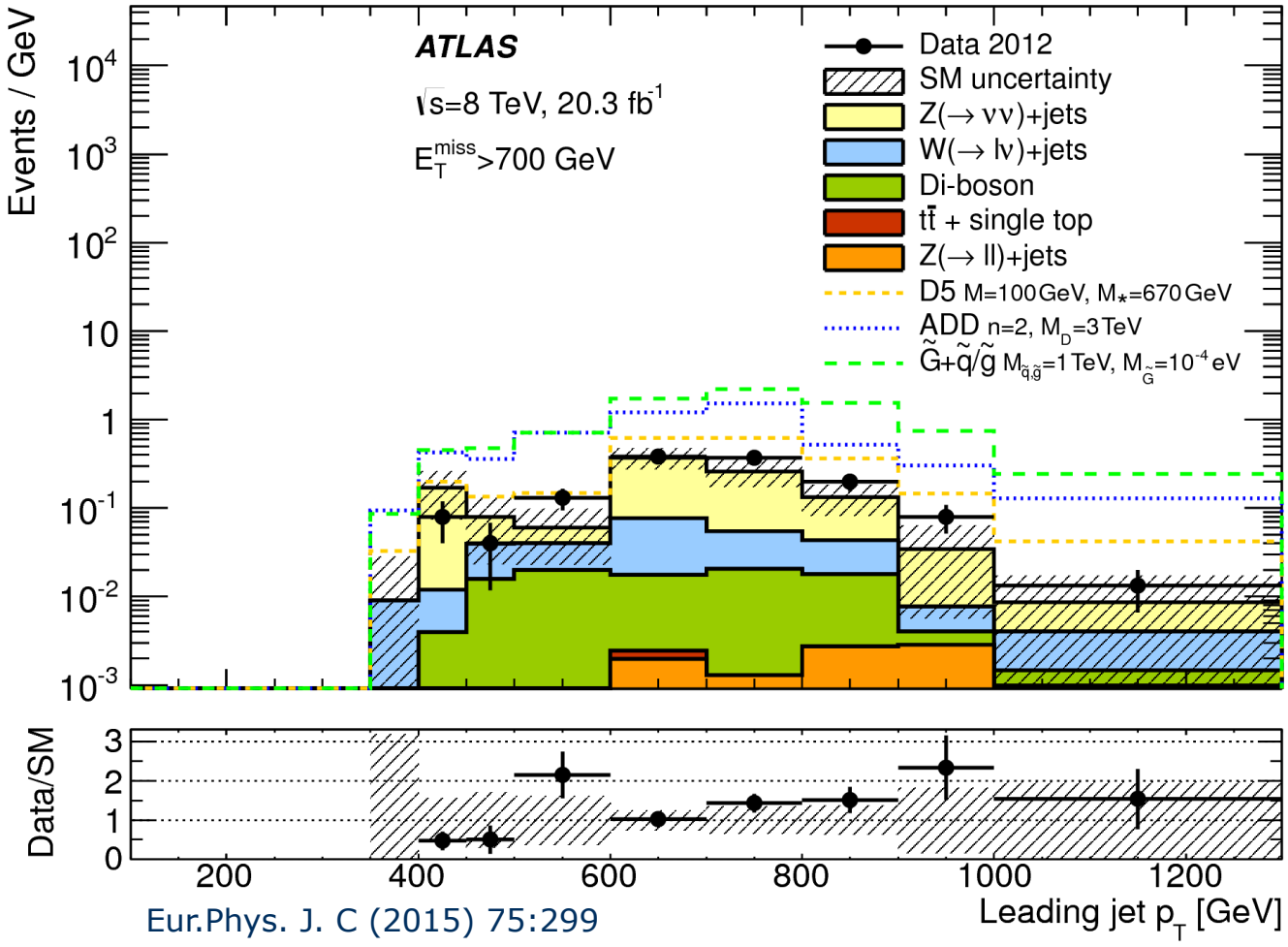

From JHEP09(2014)176

# Limit on $M_*$




Observed and truncated limits on $M_*$ ($\sim M_{med} / \sqrt{g_{DM} g_{SM}}$)

# Signal region 9

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