Dark matter searches with the ATLAS detector

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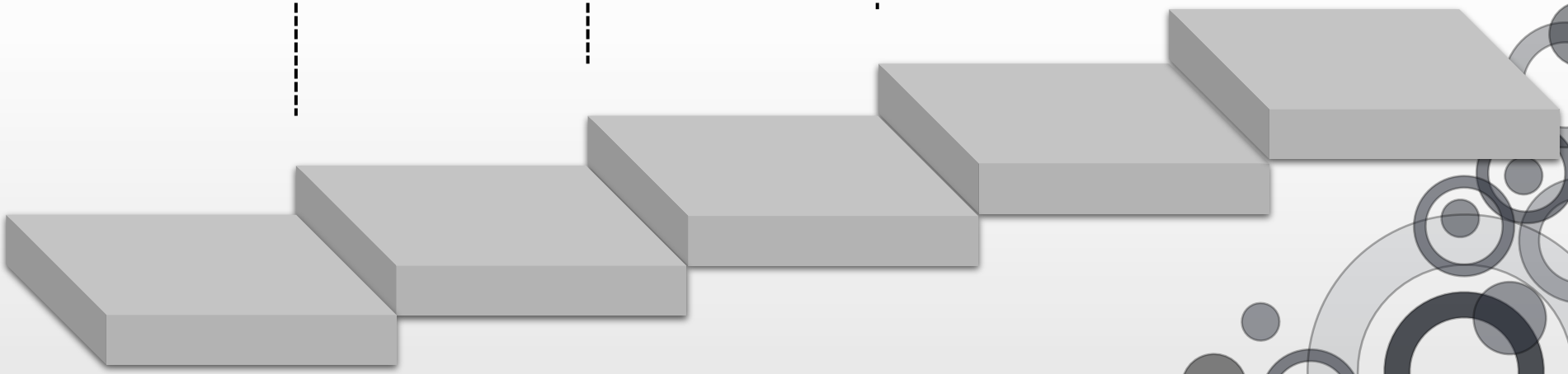
ATLAS EXPERIMENT

LPSC Grenoble
Laboratoire de Physique Subatomique et de Cosmologie

cnrs
dépasser les frontières

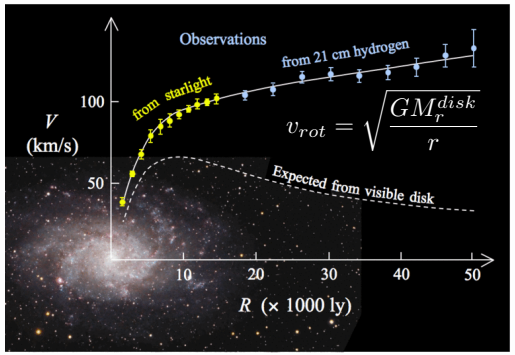
Exposure to Dark matter

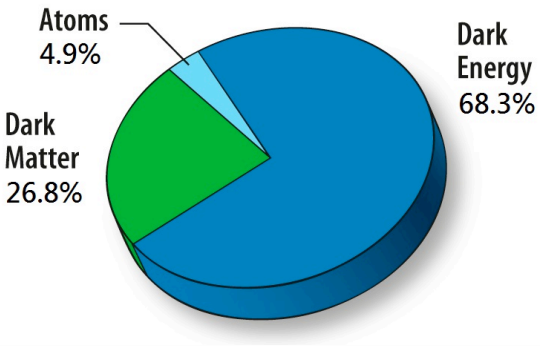
Motivation	A general strategy	Three analyses @8TeV as examples	Four models as examples	Towards 13TeV



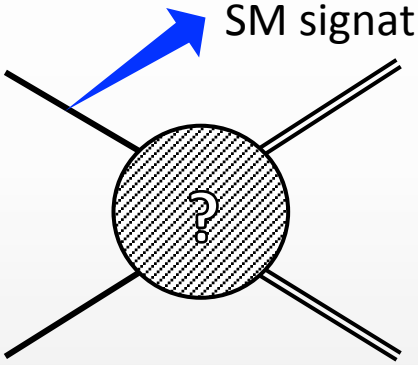
Motivation

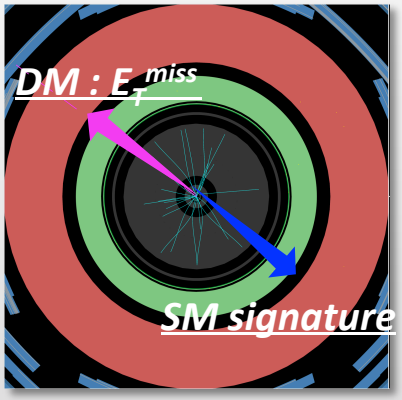
- Many proofs of the dark matter (DM) existence



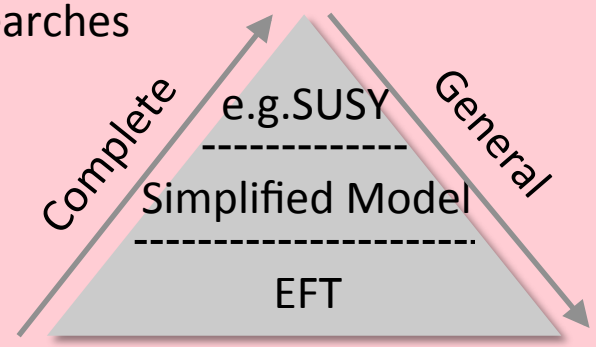


its nature and interactions with Standard Model (SM) particles are still unknown





- At colliders, DM particles could be produced in pair and be probed through the production of an associated SM particle with high transverse momentum (p_T)
- Leading to different final states :
  γ / jet / $W^{\pm}$ / Z^0 / Higgs / heavy flavour
  + missing transverse energy (E_T^{miss})
- Complementary way to probe DM : compare with results from direct and indirect DM searches
- Various models :
  effective field theories (EFT),
  simplified model,
  or complete theories
  e.g. supersymmetry (SUSY)



A General Strategy

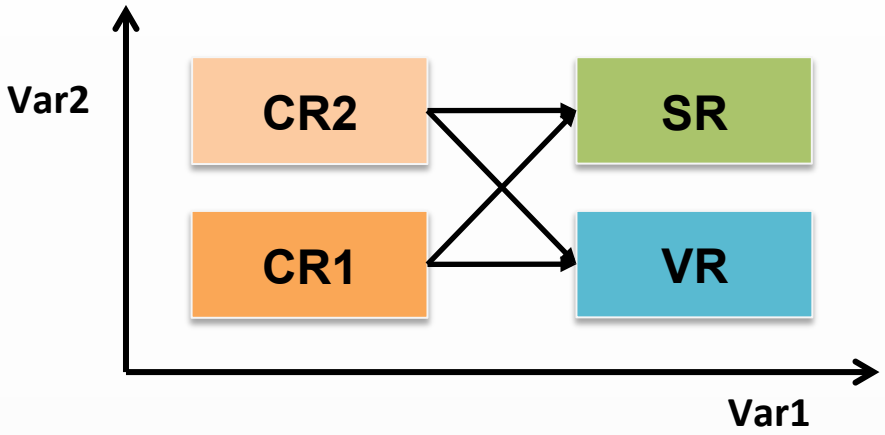
Define Signal enriched Region (SR)

Define Control Regions (CR) with certain background processes enriched in order to normalize the MC expectation in the SR

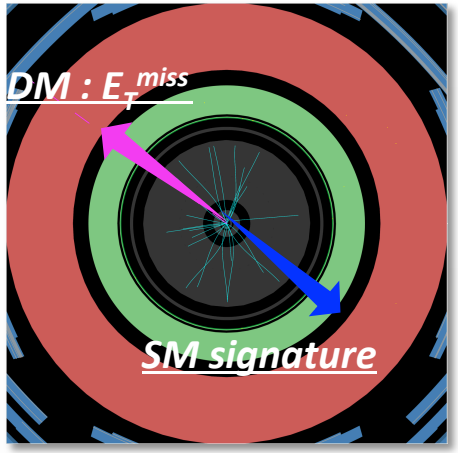
Validate the background estimation technique in a Validation Region (VR)

Un-blind data in SR to check if a significant excess is observed

If no excess is found, the results are interpreted in terms of limits on selected models.



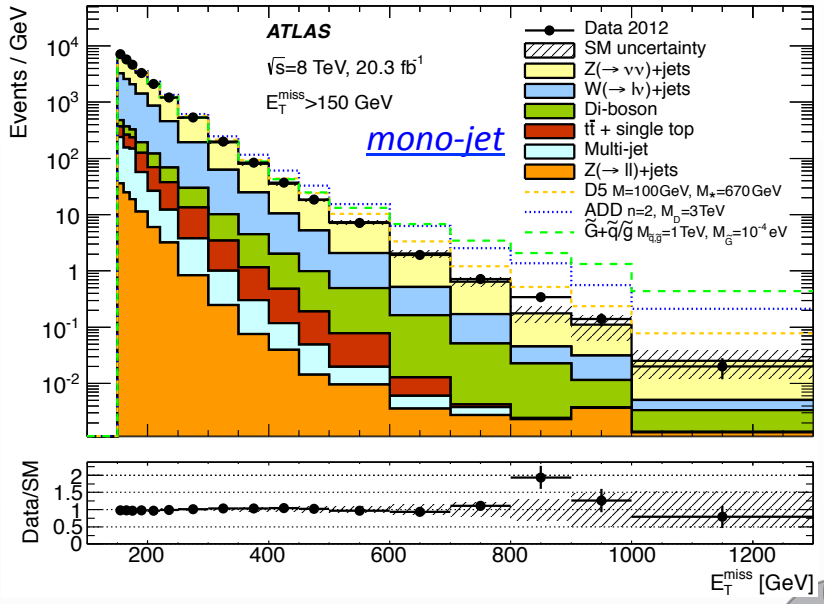
Three analyses as examples



Mono-jet

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

- Large E_T^{miss} + one central high-p_T jet, well separated from E_T^{miss}
- Lepton veto



Mono-Z(ll)

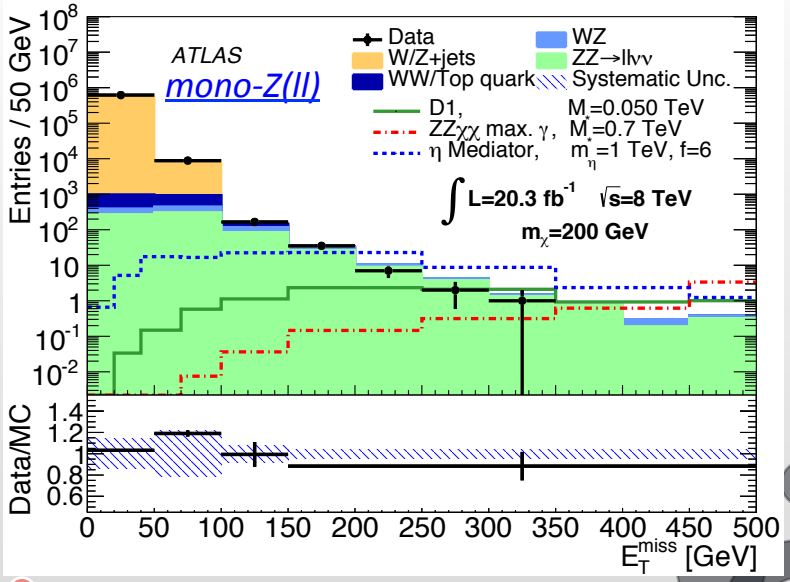
Phys. Rev. D. 90, 012004 (2014)

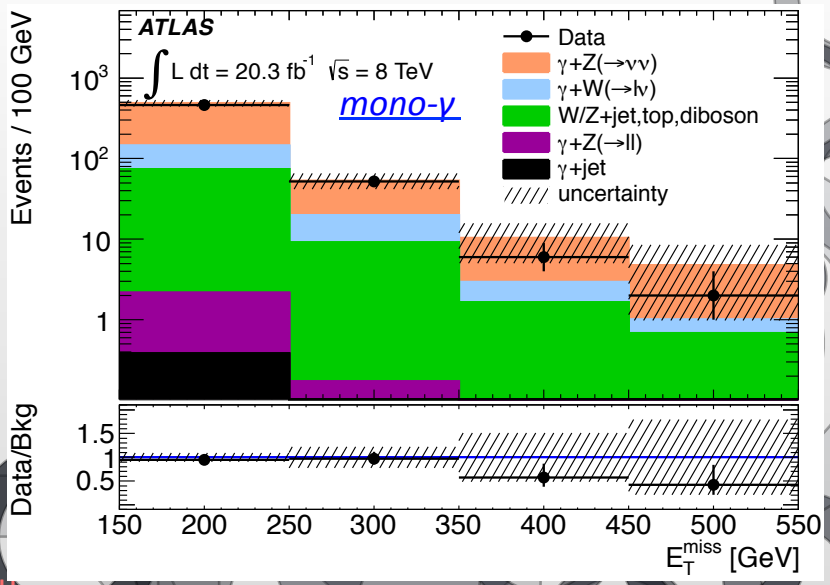
- Large E_T^{miss} + a well-identified Z(ll), well separated from E_T^{miss}
- Jet veto

Mono-γ

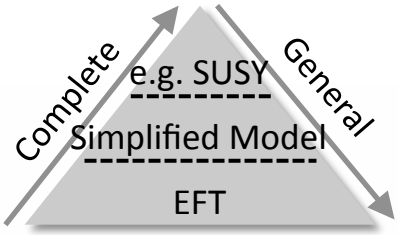
Phys. Rev. D 91, 012008 (2015)

- Large E_T^{miss} + one central high-p_T photon, well separated from E_T^{miss}
- Lepton veto





Four models as examples



1 A General EFT Model

For a given effective operator

Less free parameters

- Effective energy scale M_*
- Dark matter mass m_χ

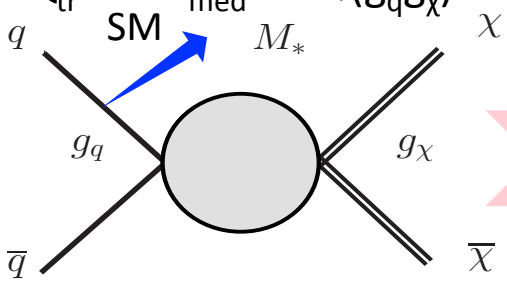
Compute the excluded M_*

- $M_*^{exclude} = M_*^{generated} (\sigma^{theo}/\sigma^{excluded})^{1/2p}$, where 'p' is the power of $(1/M_*)$ in the EFT Lagrangian

EFT validity truncation:

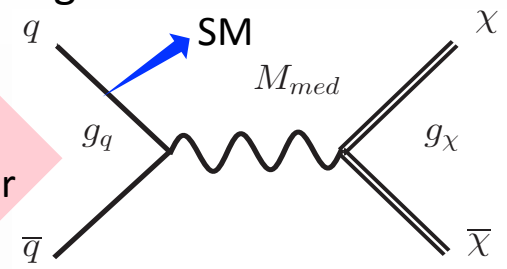
- Remove events generated not satisfying $Q_{tr} < M_*(g_q g_\chi)^{1/2}$

$Q_{tr} << M_{med} = M_*(g_q g_\chi)^{1/2}$



explicit mediator

e.g. Z'-like vector mediator



2 A Simplified Model

Removes problem of validity

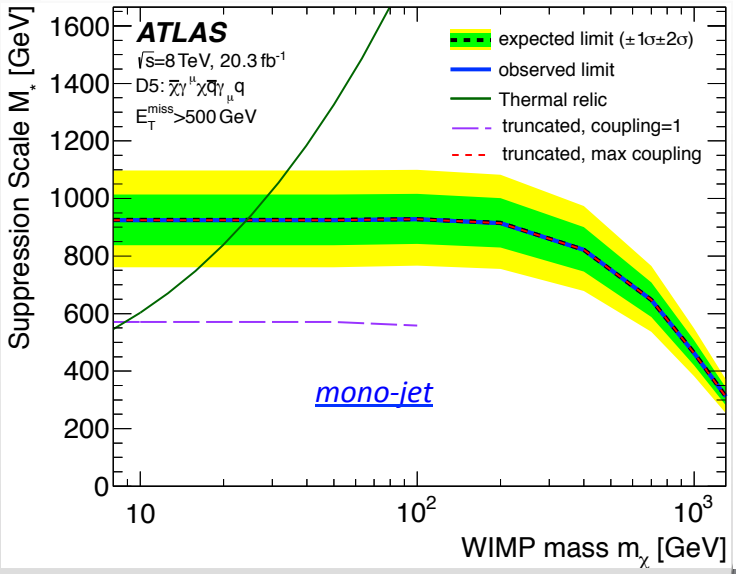
More free parameters

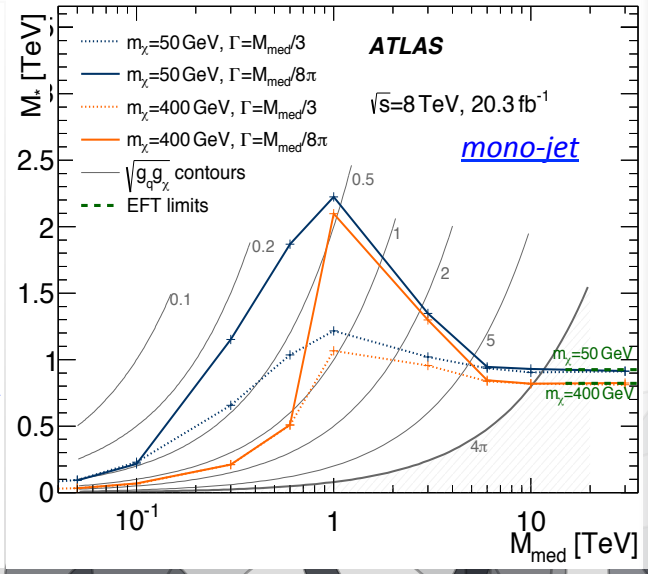
- m_χ and $g_q g_\chi$
- Mediator type and its parameter: mass M_{med}, width Γ (related to $g_q g_\chi$)

Excluded M_* as a function of M_{med}

- For given m_χ and Γ, limits can be translated to M_*

  $M_* = M_{med} / (g_q g_\chi)^{1/2}$
- EFT region starts from $M_{med} > 5$ TeV





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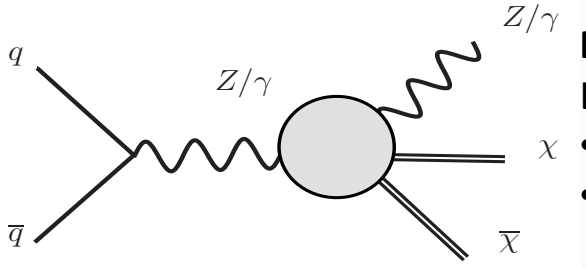
Four models as examples

3 An EFT Model Inspired by Fermi-LAT Spectrum

- A tentative DM signal at 130 GeV seen in 2012 Fermi-LAT public data
- At LHC, the nature of this signal can be probed by:



Free parameters:

- M_* and m_χ
- Electroweak coupling strengths k_1, k_2

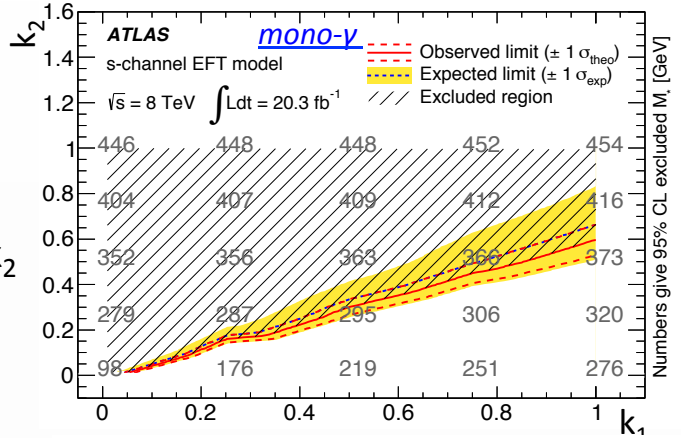
Mono-γ :

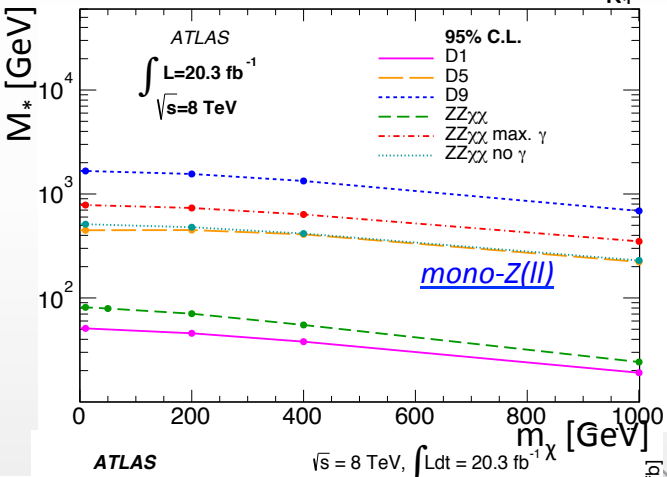
Constrain (k_1, k_2) using Fermi results

Mono-Z(ll) :

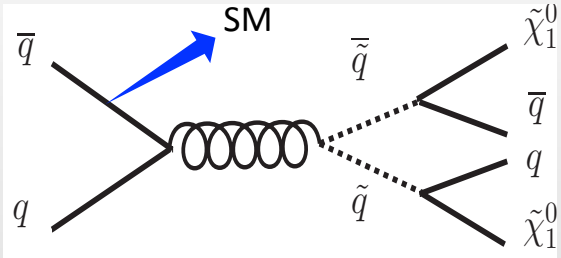
Limits on M_* for given m_χ

- no γ : for $k_1 = k_2 \cos^2\theta_w / \sin^2\theta_w$
- max. γ : for $k_1 = k_2 = 1$

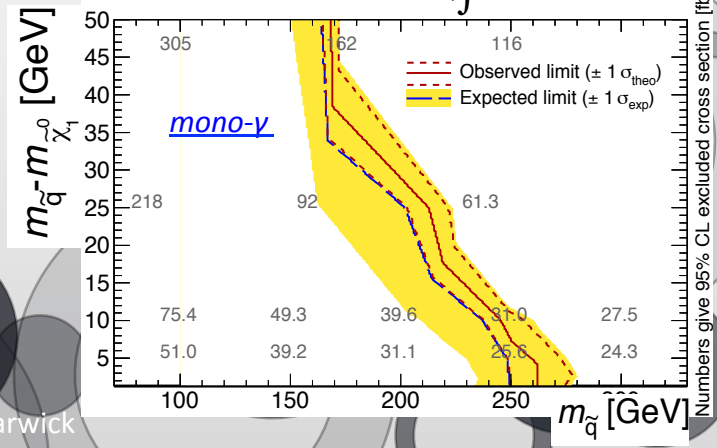




4 Lightest Neutralino in SUSY: Compelling Candidate to DM



- R-parity conserving simplified SUSY model, mass degenerate 1st and 2nd generation squarks
- $\Delta m\ \tilde{q}, \tilde{\chi}_1^0 \leq O(10\ \text{GeV}) \rightarrow X + E_T^{miss}$



Phys. Rev. D. 90, 012004 (2014)
Phys. Rev. D 91, 012008 (2015)

Towards 13 TeV

- ✓LHC started to run at 13TeV in June
- ✓Studies are ongoing:
  - **Mono-γ :**
    Trigger fully efficient in the SR
  - **Mono-jet :**
    Good data/MC agreement on E_T^{miss} in CR