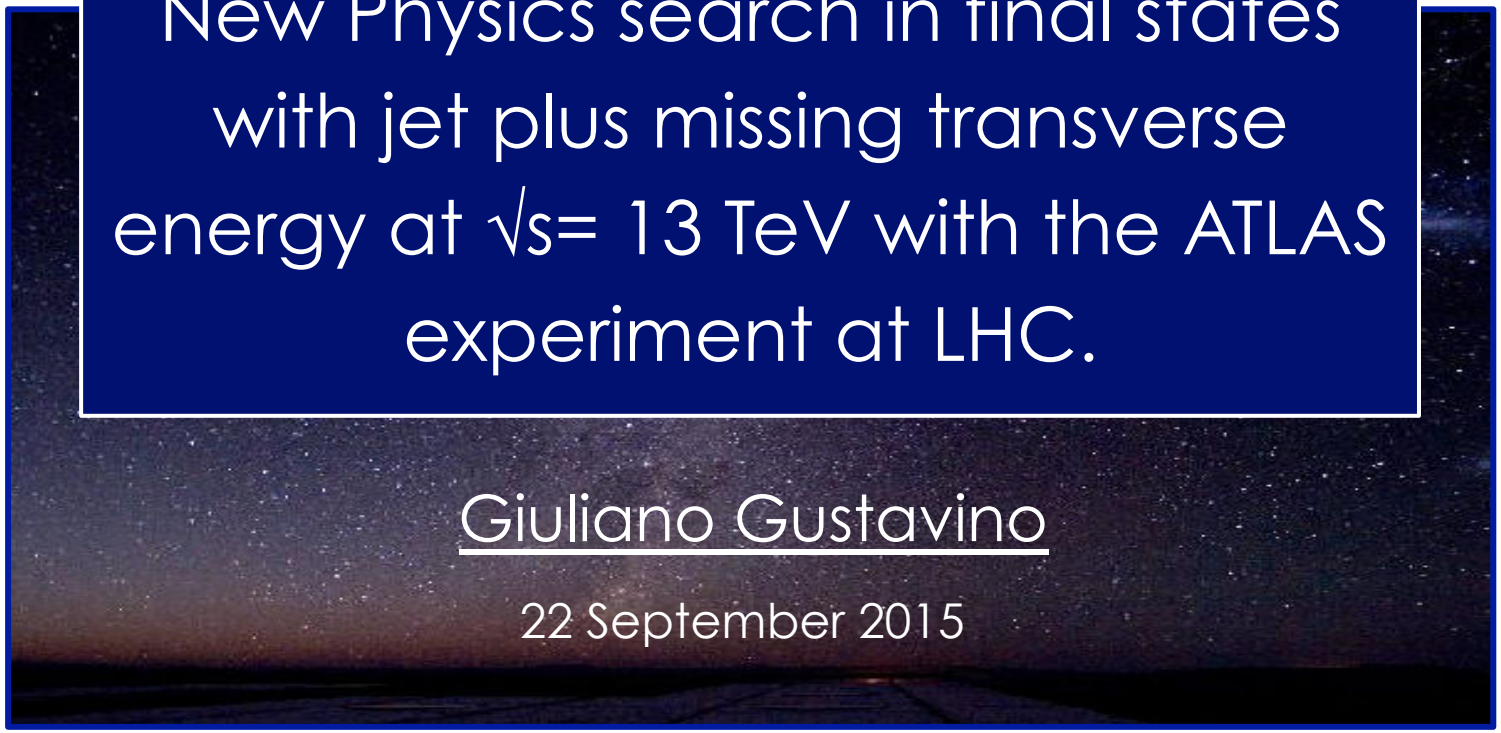
New Physics search in final states with jet plus missing transverse energy at $\sqrt{s}$= 13 TeV with the ATLAS experiment at LHC.



Giuliano Gustavino

22 September 2015

101° Congresso della Società Italiana di Fisica

SAPIENZA
UNIVERSITÀ DI ROMA

ATLAS EXPERIMENT

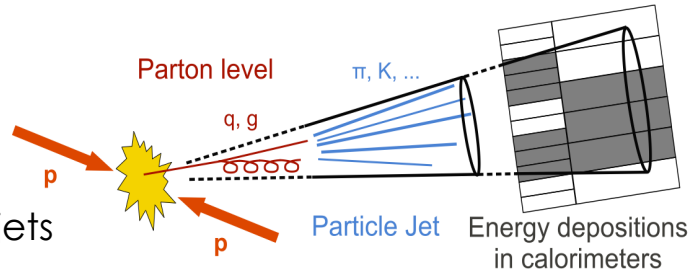
INFN
Istituto Nazionale
di Fisica Nucleare

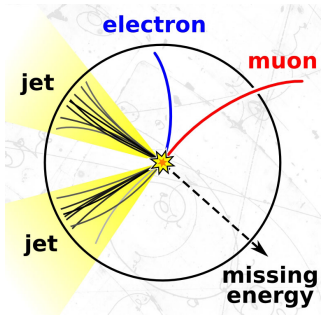
Introduction

The Mono-jet analysis is a search for events with a high transverse momentum jet and missing transverse energy (E_T^{miss}) in the final state.

What is a jet?

Hadrons are clustered together to make particle jets



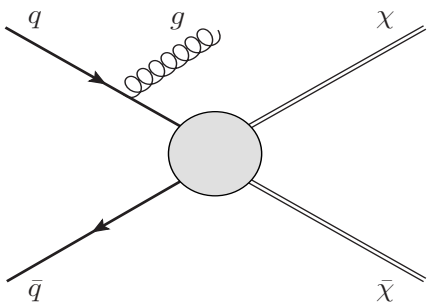


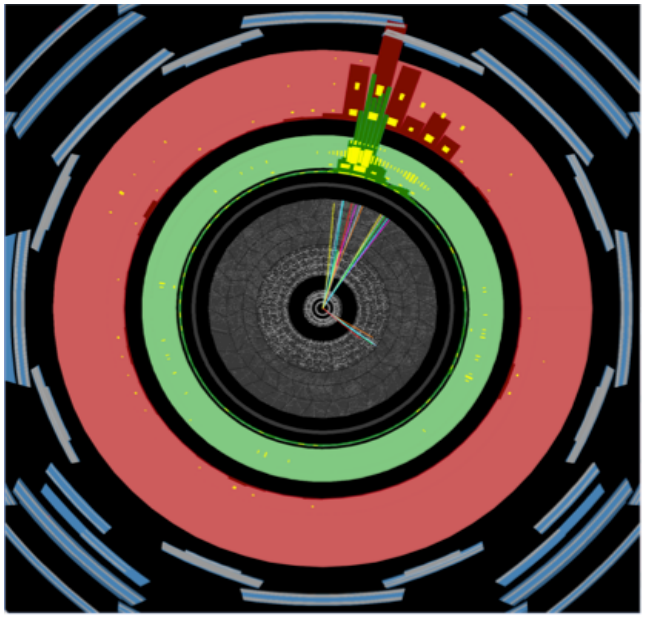
What is MET?

MET measures the energy imbalance in the plane transverse to the colliding proton beams

This topology constitutes a clean and **distinctive signature in searches for New Physics** beyond the Standard Model (SM) at colliders.

The Mono-jet final state has more statistics with respect to other Mono-X (Mono-photon, Mono-Higgs etc.) final states @LHC ($\alpha_S >> \alpha_{EW}$).

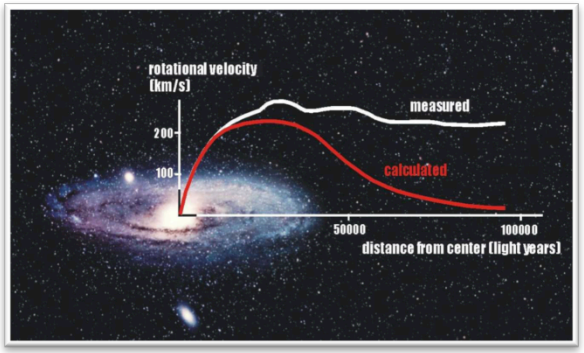




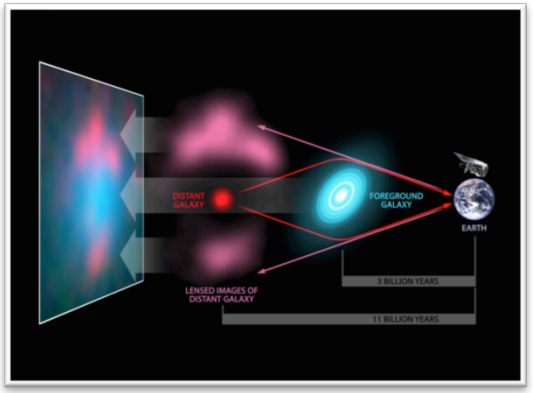
The Dark Matter paradigm

The existence of a Dark Matter (DM) particle is a well-established hypothesis that explains a range of astrophysical and cosmological measurements.

The presence of a non-baryonic component in the universe is inferred from the observation of its gravitational interactions

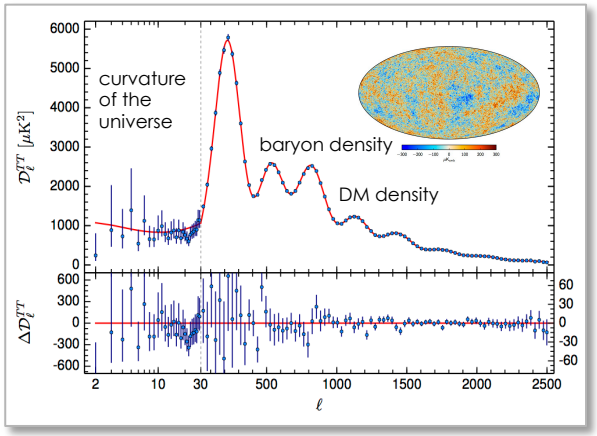


Velocity found to be flat, consistent with ~10x as much "dark" mass for more than one galaxy



visible mass not sufficient to explain observed lensing effect

Dynamics collision of galaxies in bullet cluster not explained with only the baryonic matter



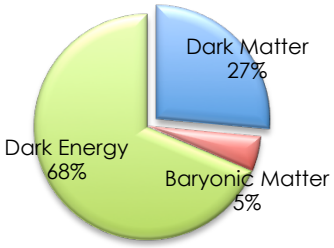
Baryonic matter alone can't produce the CMB spectrum

arXiv:1502.01582v2

NASA Link: http://lambda.gsfc.nasa.gov/education/cmb_plotter/

The Dark Matter paradigm

None of the known SM particles provides suitable candidates for DM, since several theories beyond the SM postulate the existence of new particles that are **stable** (or at least long-lived) and **neutral.**

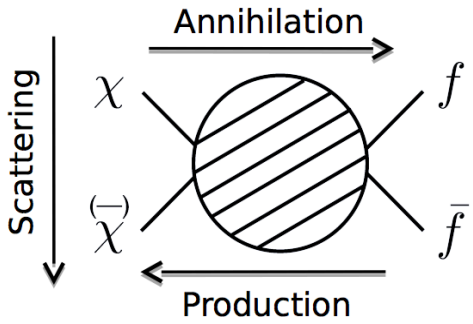


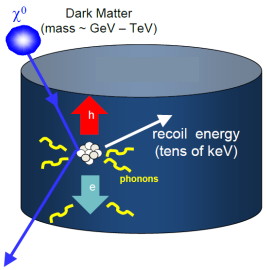
After Planck results

➡ **WIMP** (Weak Interactive Massive Particle)

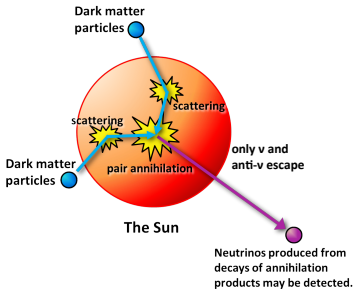
How can we study the Dark Matter?

- **direct detection** based on scattering interaction detections (DAMA, LUX etc.)
- **indirect detection** experiments that look for final states given by the DM annihilation (AMS, Ice-Cube etc.)
- Pair **production at LHC** with large missing energy in the detector





example of direct detection

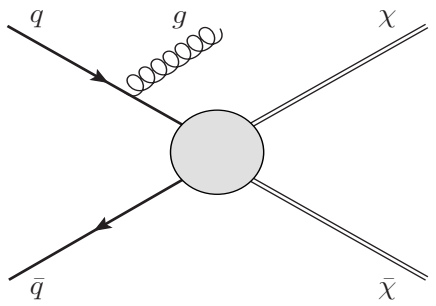


example of indirect detection

The detection of DM candidates in a collider can give complementary results with respect to the other DM detections.

Run1 Mono-jet Analysis

Selection criteria
Primary vertex
Jet quality requirements
At least one jet with $p_{\mathrm{T}} > 30$ GeV and $\lvert\eta\rvert < 4.5$
Lepton and isolated track vetoes
The leading jet with $p_{\mathrm{T}} > 120$ GeV and $\lvert\eta\rvert < 2.0$
$E_{\mathrm{T}}^{miss} > 150, \ldots, 700$ GeV
Leading jet $p_{\mathrm{T}}/E_{\mathrm{T}}^{miss} > 0.5$
$\Delta\phi(\mathrm{jet}, E_{\mathrm{T}}^{miss}) > 1.0$

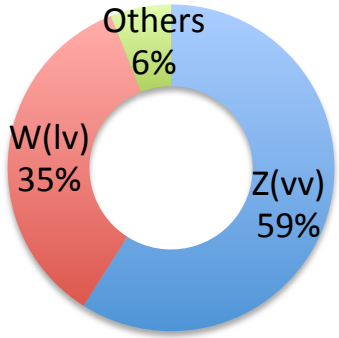


More Signal Regions defined choosing the one with the best expected limit.

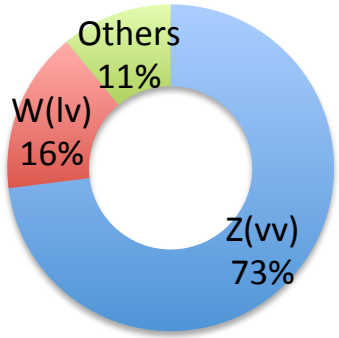
Backgrounds

- Z(νν)+jets (60-80% of the total depends from the Signal Region)
- W(lν)+jets (W(τν) is the dominant and it counts 10-20% of the total background)
- Z(ll)+jets (mis-identified leptons)
- ttbar, single top
- diboson
- Multijets
- Non-Collision background (detector noise, cosmic ray showers, beam-induced bkg, fake jets)

MET > 150 GeV



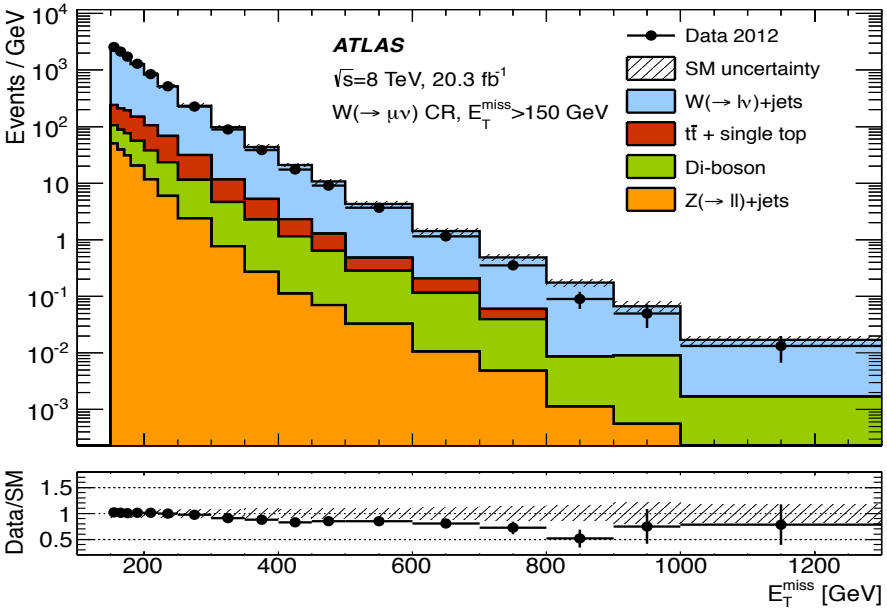
MET > 700 GeV

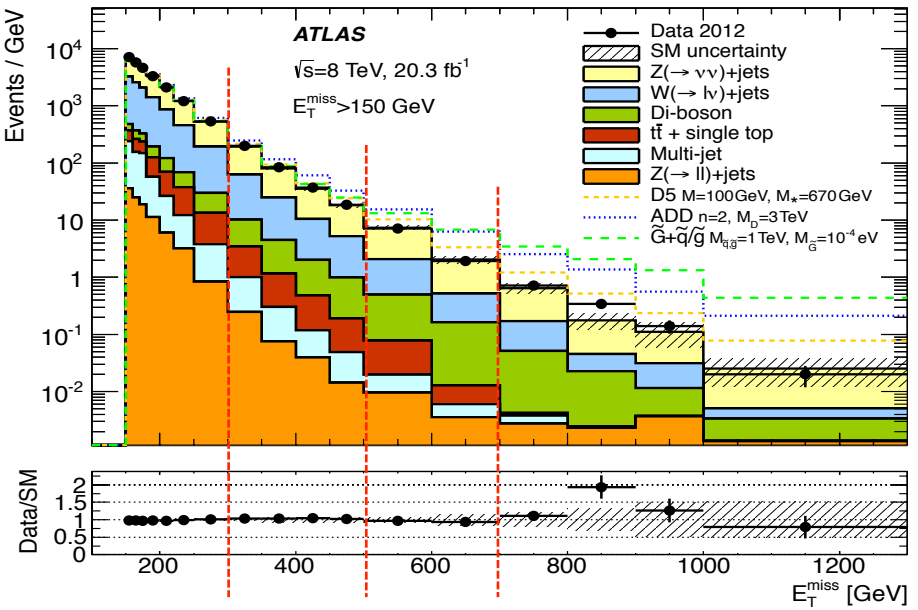


Run1 Mono-jet Analysis(2)

Z(νν)+jets is the dominant background and it is estimated by **W(μν) Control Regions**

What is a Control Region?
It's a region enriched of a desired background and it is used to constrain and extrapolate sources of background in the Signal Region through a transfer factor.





SR (E_T^{miss} cut)	300 GeV	500 GeV	700 GeV
Observed events	18020	1028	126
SM expectation	18000 ± 500	1030 ± 60	97 ± 14

The observed events are in good agreement with the expectations

bkg uncertainties ~3÷6÷14 (top, di-boson, V p_T modelling, JES/JER...)

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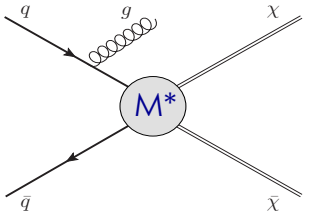
The Dark Matter interpretation

Contact interaction (Fermi-like interaction) in the Effective Field Theory can be considered if:

$$M_{med} = M^{*}(g_{SM}g_{DM})^{1/2} >> \sqrt{\hat{s}} >> 2m_{\chi}$$



Several operators that descibe the type of interaction are investigated considering DM a Dirac fermion or scalar WIMP (Weak Interactive Massive Particle)…

comparison with direct detection experiments

Limit on Spin independent and Spin dependent χ-nucleon interaction xsec

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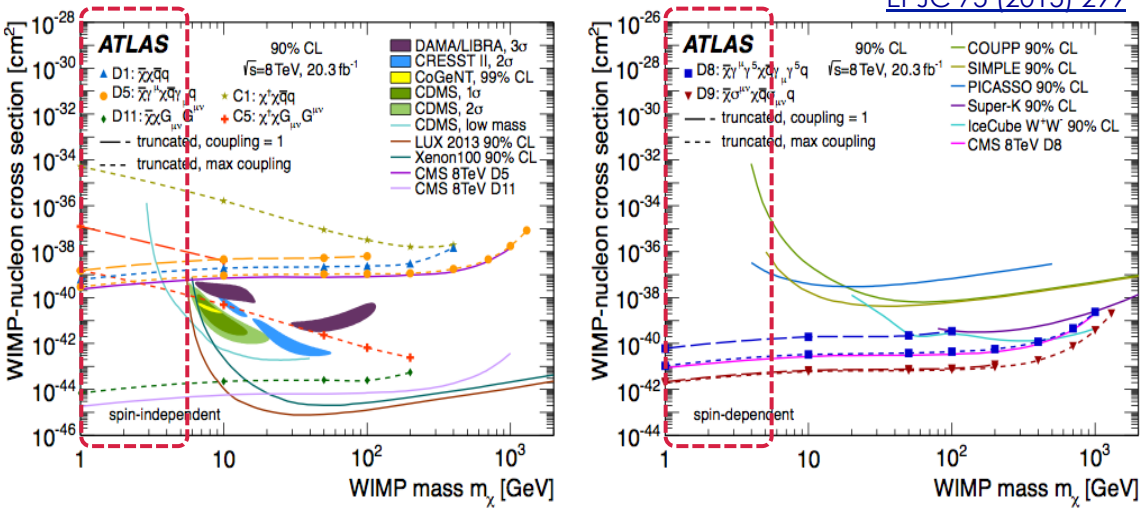

The direct search is sensitive in the **low Dark Matter mass m_{χ}** region (current direct detection experiment are not sensitive to GeV mass WIMPs).

Simplified Models

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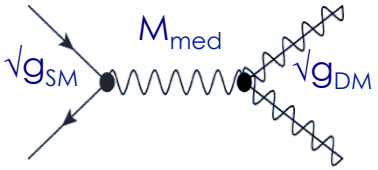
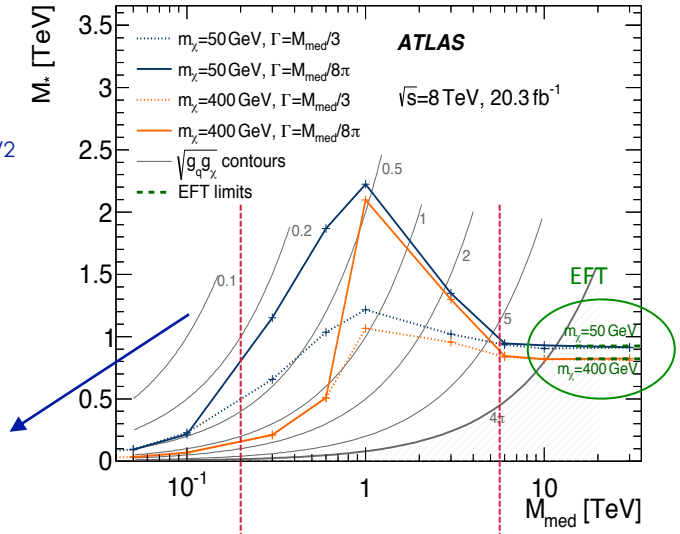
But @LHC we can do more!
In fact we can really say more than simple Initial State Radiaton EFT choosing a particular kind of mediator ***(Simplified Models)***



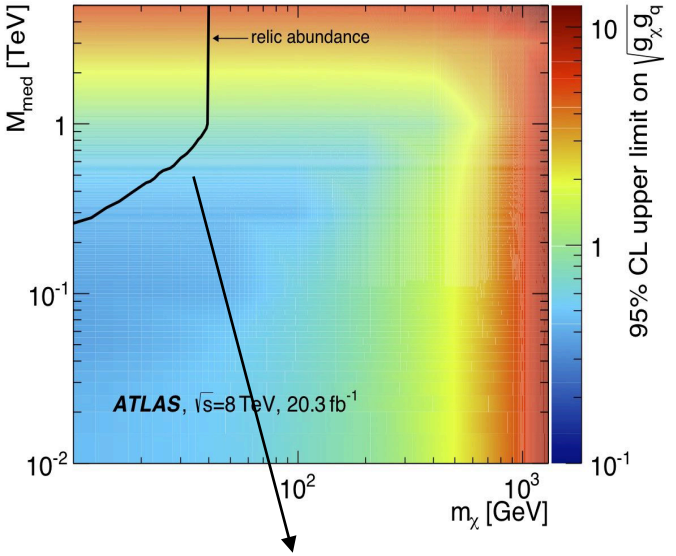
We can set constraints on the couplings ($\sqrt{g_{SM}g_{DM}}$) studying the relation between M^* and M_{med} in a 2D plane M_{med} vs m_χ in a Simplified Model escaping from the Effective Fields theories hypotheses!

Limits on DM particles which couple to SM quarks via a Z' boson

$$M^* = \frac{M_{med}}{(g_{SM}g_{DM})^{1/2}}$$



constant coupling contours



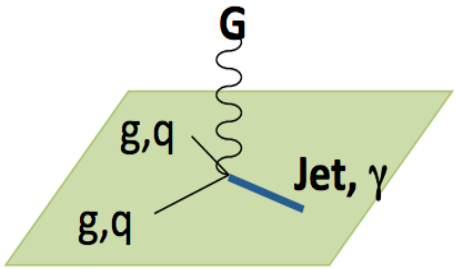
relic abundance as measured by the WMAP satellite, assuming annihilation in the early universe in the absence of any interaction other than the one considered.

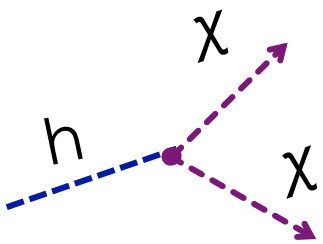
EFT results optimistics

EFT results pessimistics

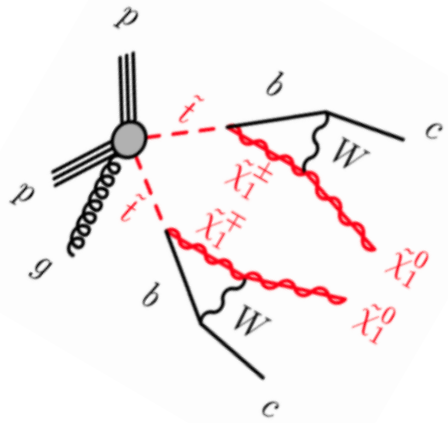
limit of high M_{med} is the EFT ($M_{med} >> \sqrt{s}$)

Other Interpretations





We don't want to get hung up on the Dark Matter side!



Other Interpretations

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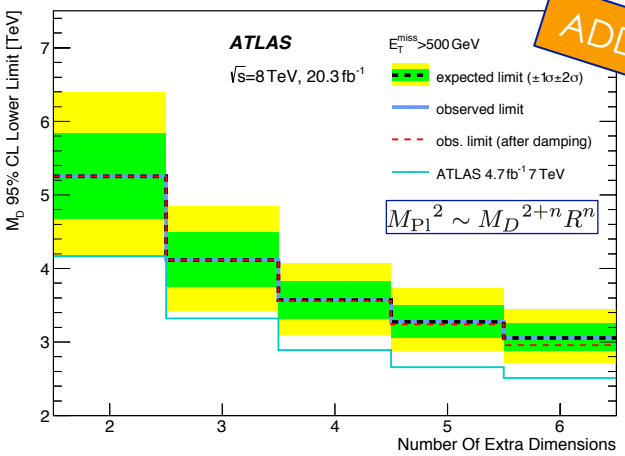
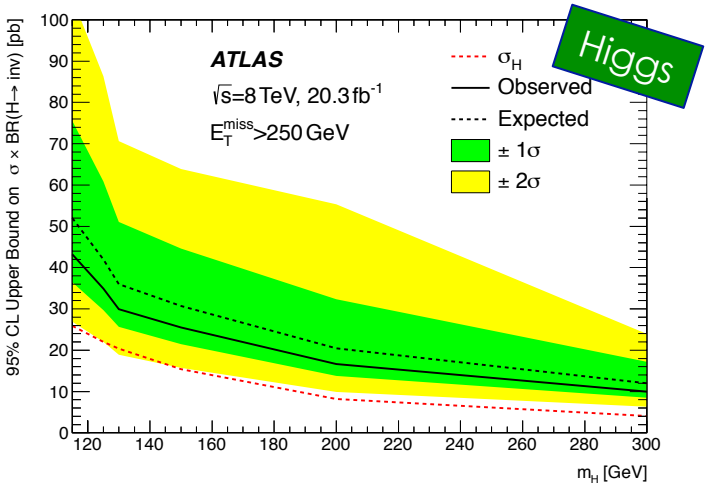
ADD

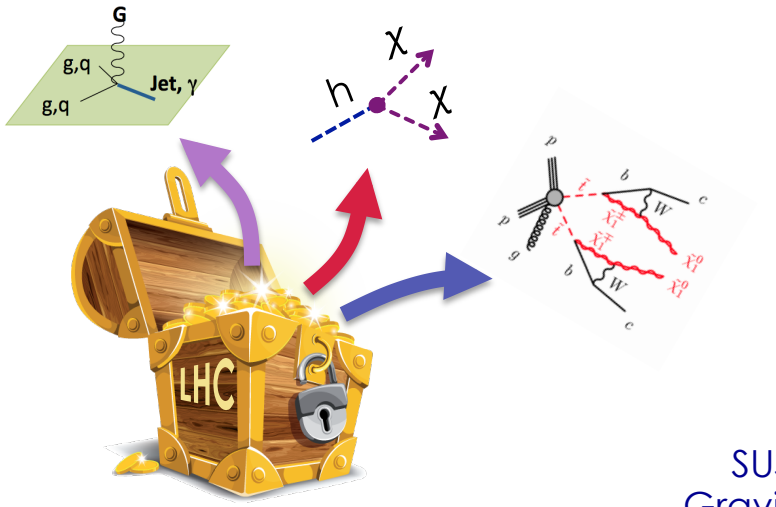


Jet + graviton modes escaping detection. We can investigate the scenarios with several number of extra dimensions;

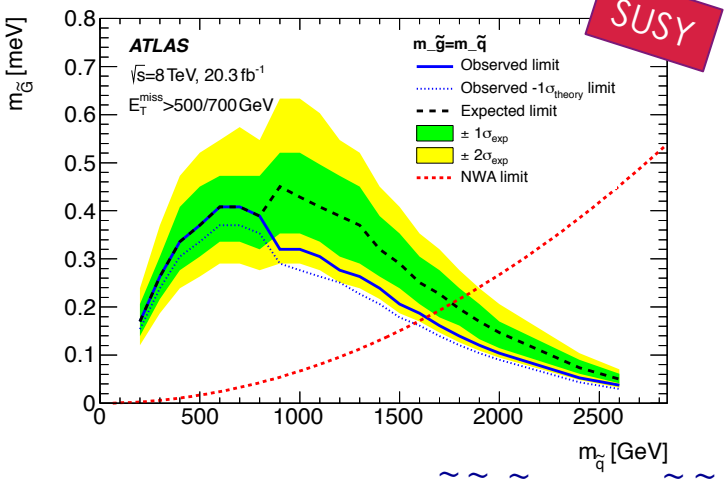
Higgs



Invisible Higgs decays are also investigated (sizable BR still allowed).



SUSY



SUSY with LSP Gravitino $pp \rightarrow \tilde{G}\tilde{g}(\tilde{q})+X \rightarrow \tilde{G}\tilde{G}g(q)+X$
Gravitino mass constraints can be set in several scenarios

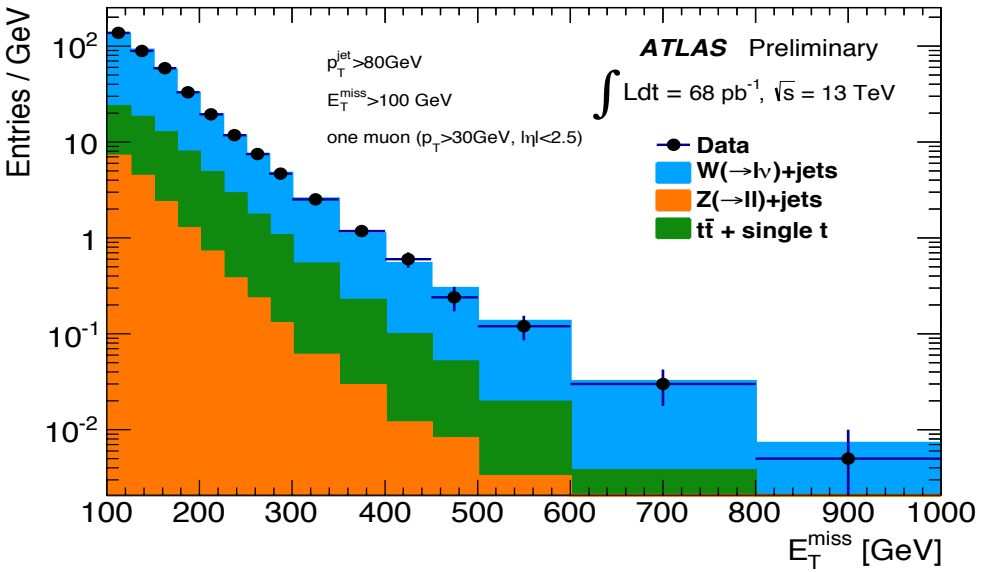
Run2 work in progress

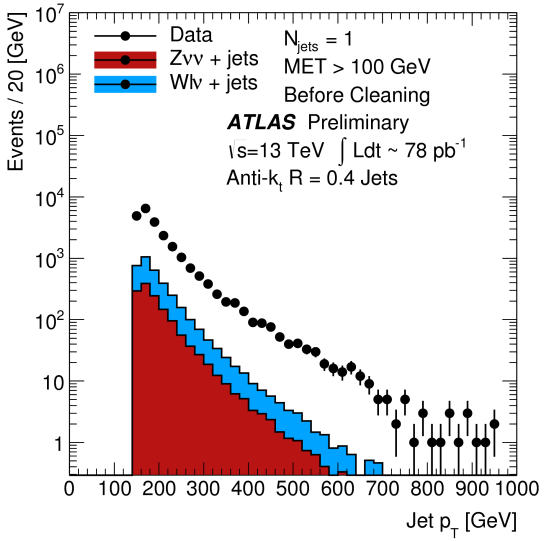
For the Run2 Analysis similar Run1 event selection strategy adapted the new collision energy:

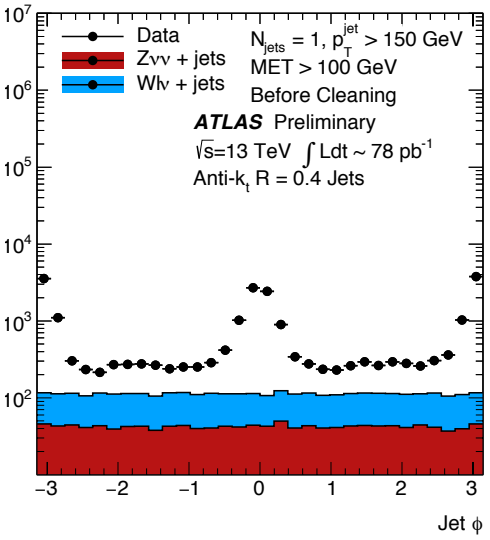
- new definitions of the object requirements
- higher jet p_T and MET cuts;
- added cut on the jet multiplicity
- adapted cuts for the multijet background
- …

First public results with 68-78 pb^{-1} of data using 'relaxed' definitions that show our control of the non-collision background (by removing the jet cleaning) and our readiness to use the new data…

EXOT-2015-005



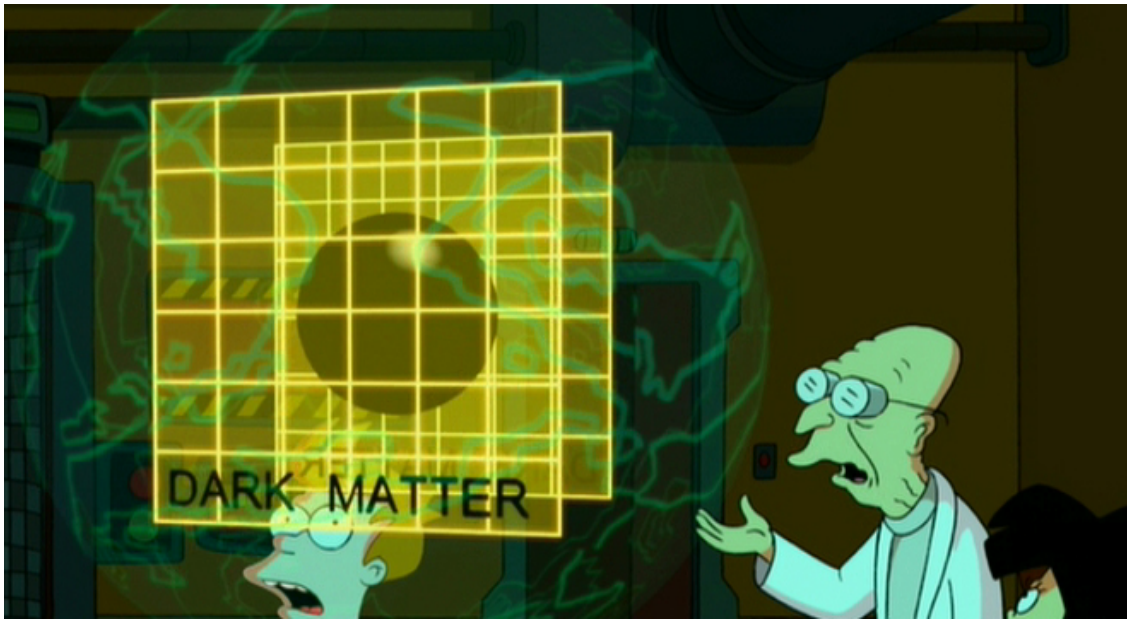




Conclusions

The Dark Matter paradigm is one of the biggest unknown mysterious of the universe.

The experiments at LHC have just started to give their crucial contribute in its search during the Run1.
Mono-jet is the final state that can give the best results in most of the possible Dark Matter scenarios studied and not just (ADD, invisible Higgs decays, SUSY)!



Promising prospects at the new energy!

The Run2 projections show that it is possible to gain in sensitivity, compared to the results at 8TeV, with a few fb^{-1} of data collected.

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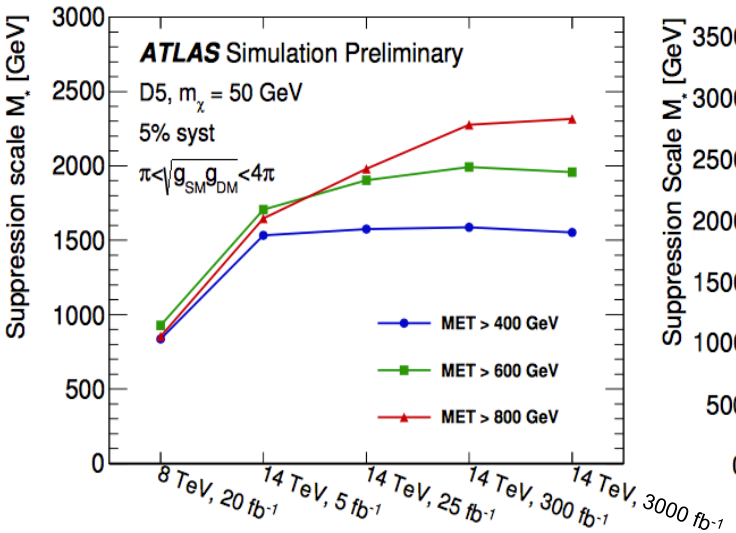
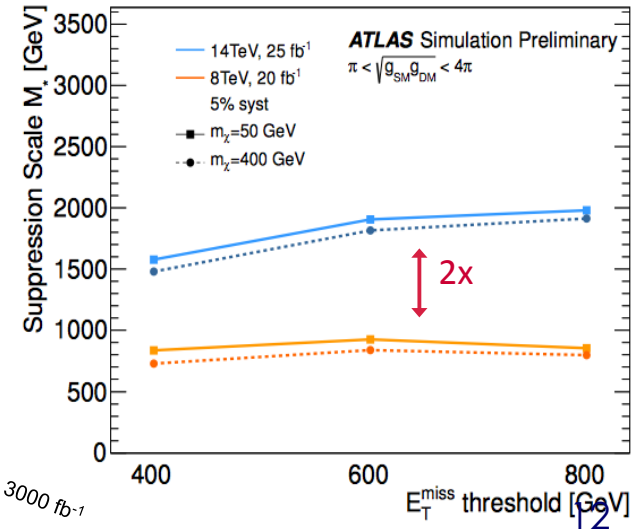


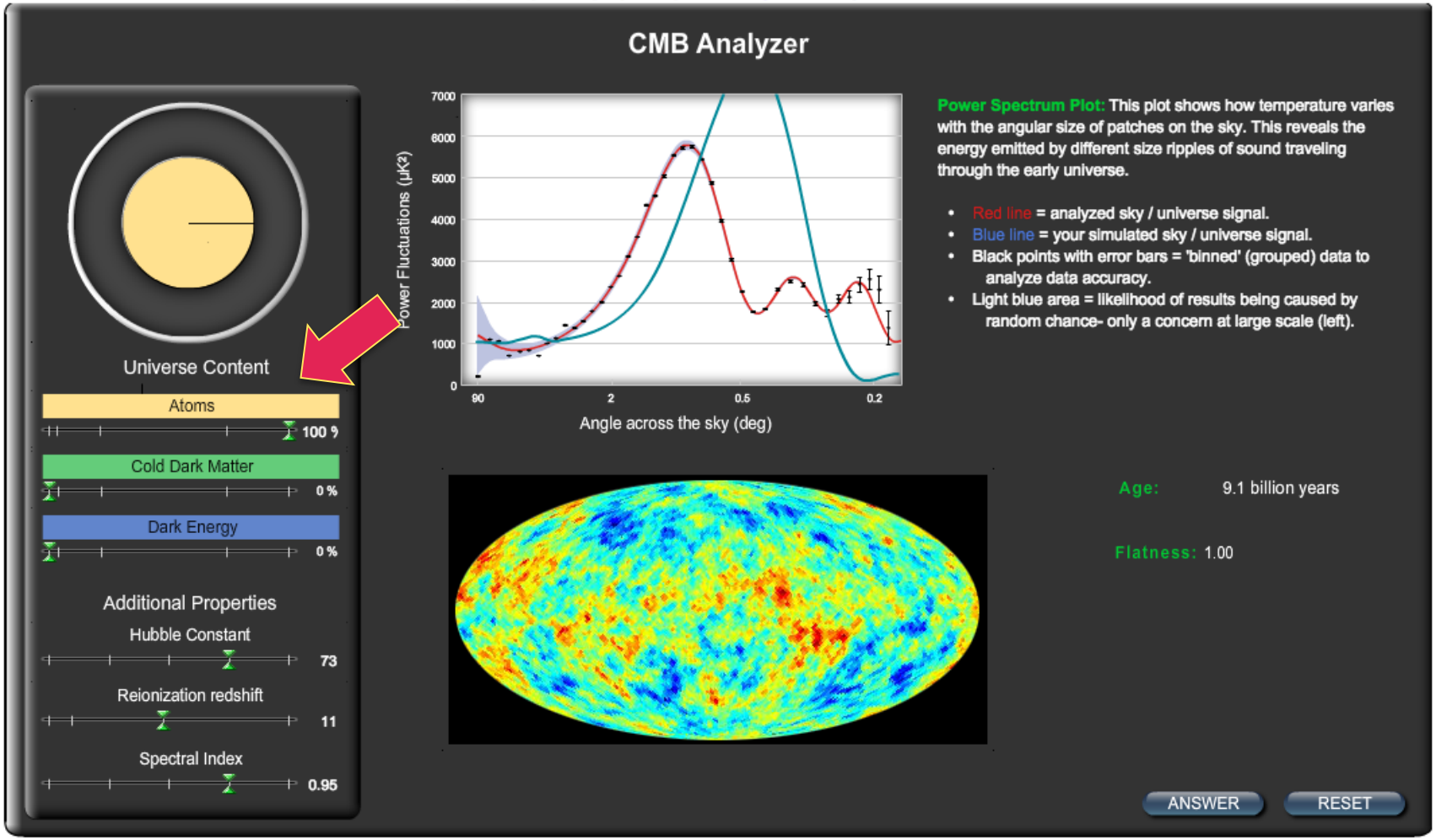


Backup Slides

The Dark Matter paradigm

http://lambda.gsfc.nasa.gov/education/cmb_plotter/

Only Baryonic Matter



The Dark Matter paradigm

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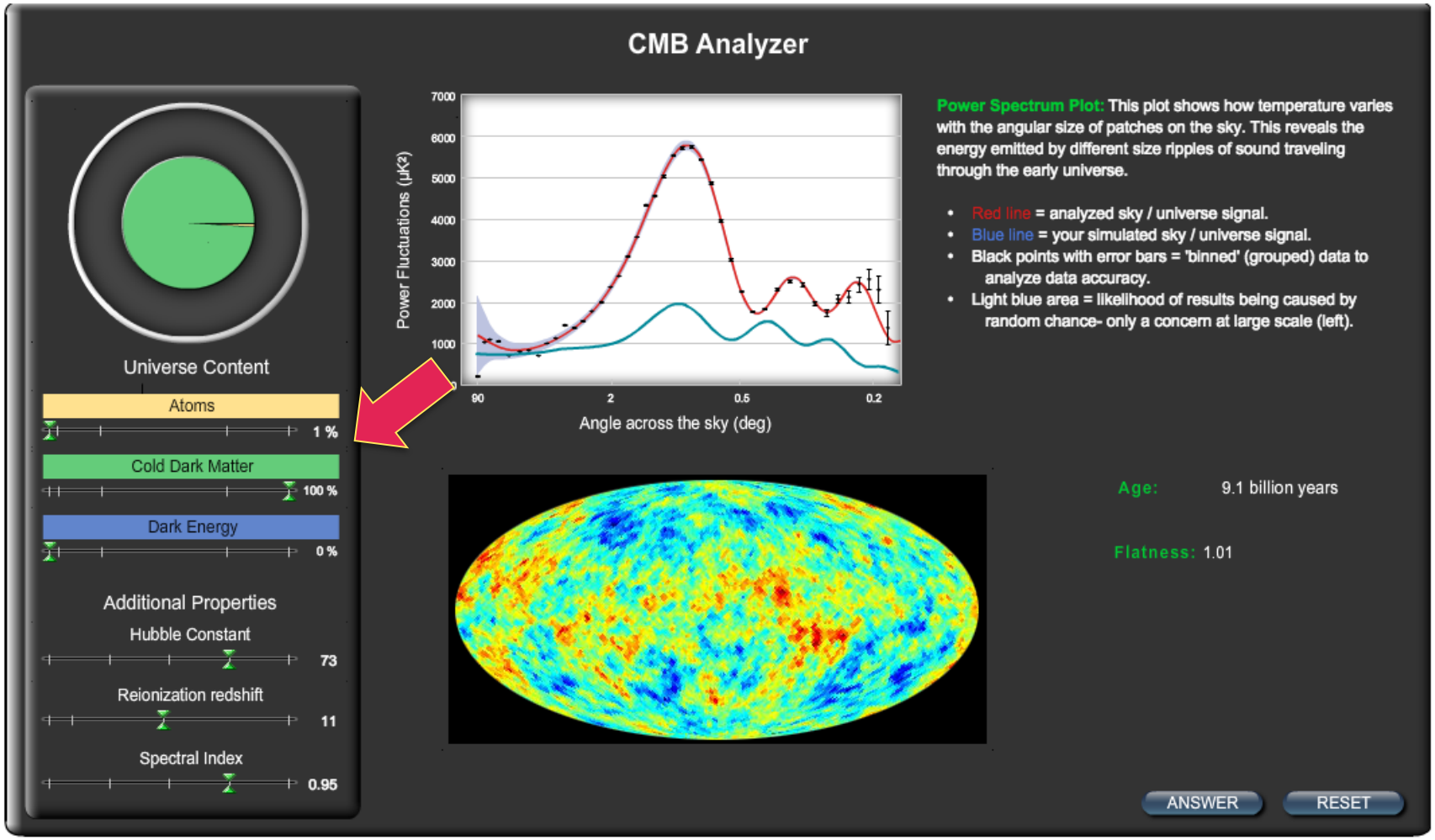
Only Dark Matter



The Dark Matter paradigm

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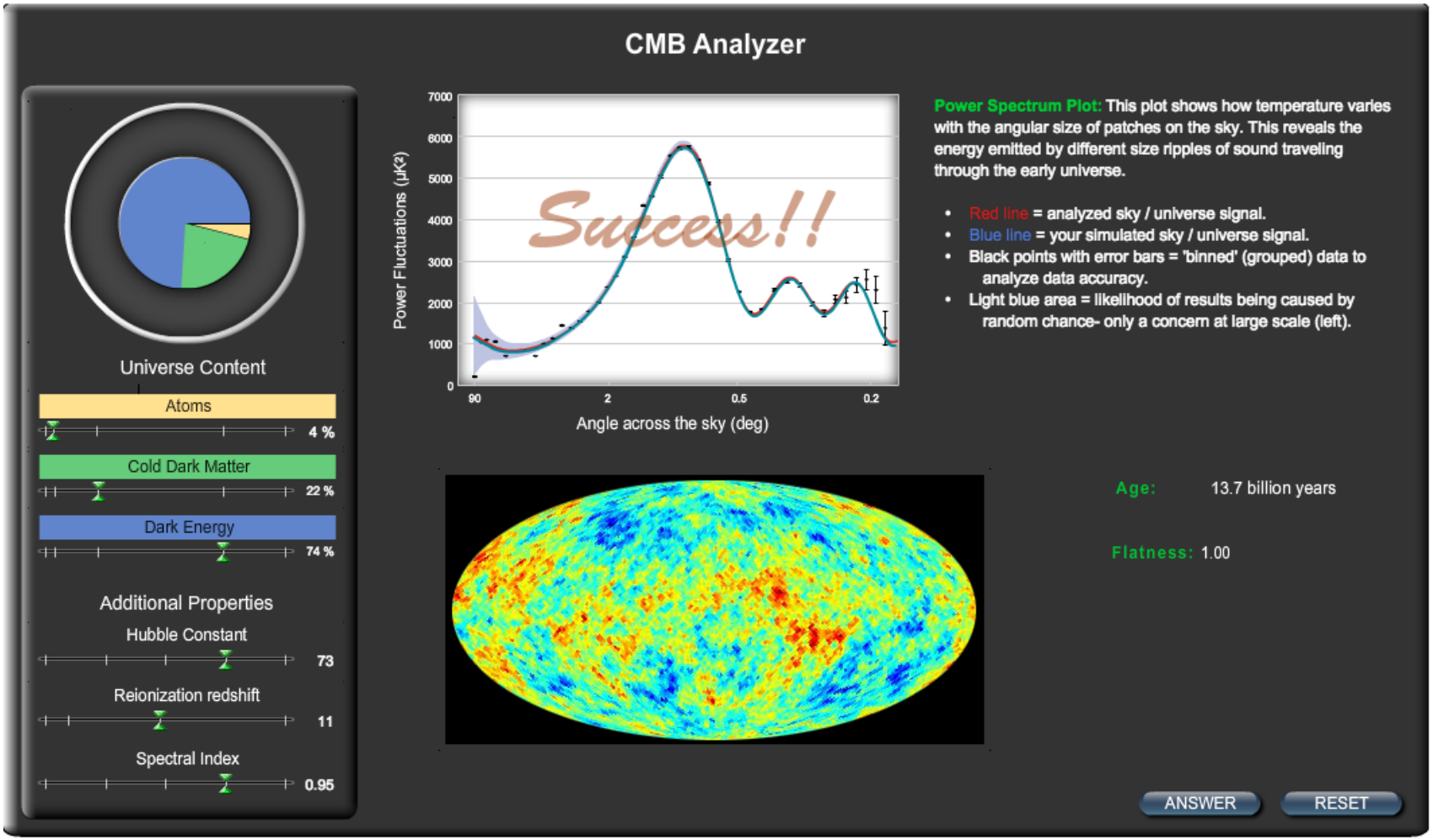
Right Mixture!

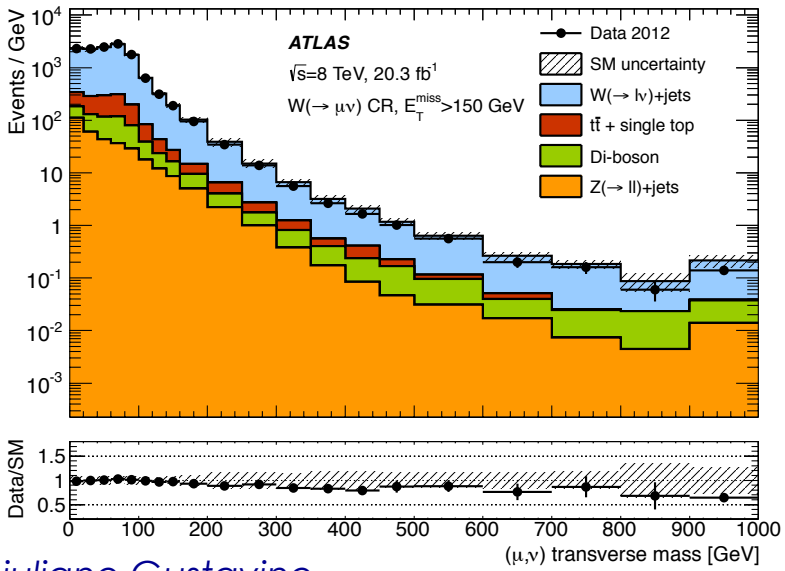


Control Regions

Do you have a too big bkg uncertainty given by a particular source of bkg? Let's try to estimate it using the data with a Control Region!

What is a Control Region?
It's a region enriched of a desired background and it is used to constrain and extrapolate sources of background in the Signal Region through a transfer factor.

$$N_{\text{signal}}^{W(\to\mu\nu)} = \frac{\left(N_{W(\to\mu\nu),\text{control}}^{\text{data}} - N_{W(\to\mu\nu),\text{control}}^{\text{non}-W/Z}\right)}{N_{W(\to\mu\nu),\text{control}}^{\text{MC}}} \times N_{\text{signal}}^{\text{MC}(W(\to\mu\nu))} \times \xi_\ell \times \xi_{\text{trg}} \times \xi_\ell^{\text{veto}}$$



Transfer factor

account for possible data–MC differences in the lepton identification, lepton vetoes, and trigger efficiencies

W(μν) CR used to estimate the dominant Z(νν) bkg

$$N_{\text{signal}}^{Z(\to\nu\bar{\nu})} = \frac{\left(N_{W(\to\mu\nu),\text{control}}^{\text{data}} - N_{W(\to\mu\nu),\text{control}}^{\text{non}-W/Z}\right)}{N_{W(\to\mu\nu),\text{control}}^{\text{MC}}} \times N_{\text{signal}}^{\text{MC}(Z(\to\nu\bar{\nu}))} \times \xi_\ell \times \xi_{\text{trg}}$$