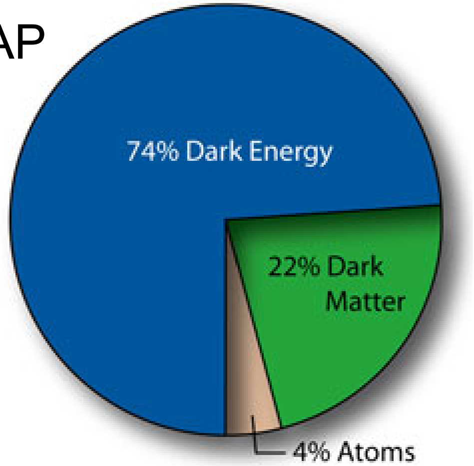
Part III: Beyond the Standard model

Motivation, BSM Higgs Searches, SUSY Searches & Exotica

Why do we need physics Beyond the Standard model?

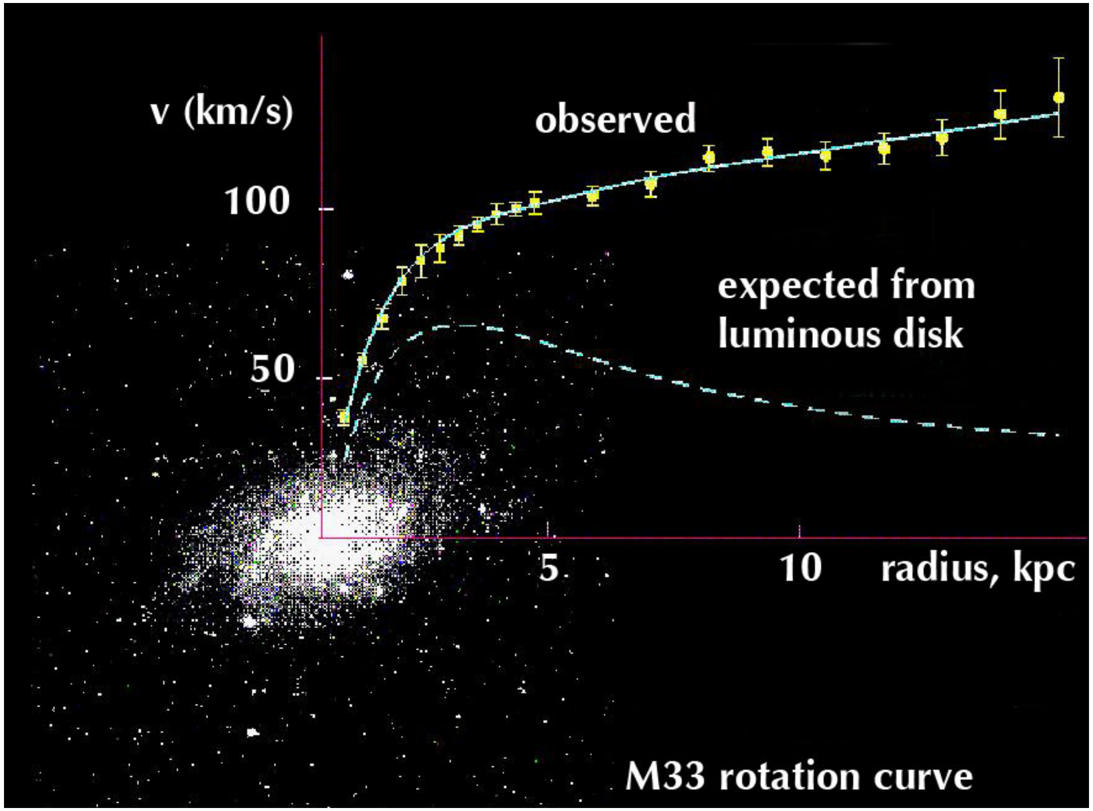
Dark matter problem

WMAP



The rotation velocity of stars in galaxies differs a lot from the expectation!
The expectation is based on the mass density of the luminous matter.
→ There must be a huge mass around the galaxies that we don't see.

Another evidence: Graviational lensing.



Observed first by V. Rubin around 1970

The standard modell does not offer any **candidate for the dark matter**:

- must be electrically neutral (otherwise we would see it)
- must be massive
- must be stable

Neutrinos? Probably not, they are too fast
→ cannot form lasting structures

Btw, another solution to this is a modification of gravity.

Why do we need physics Beyond the Standard model?

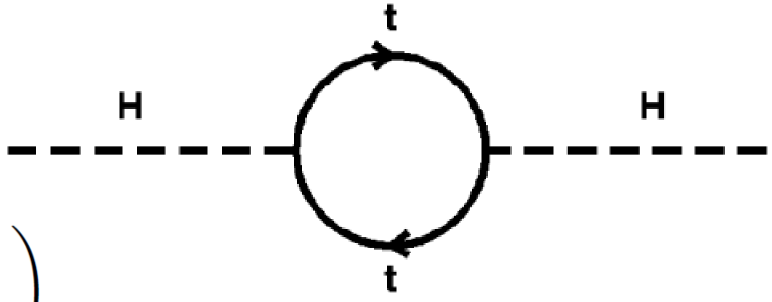
Fine-tuning problem

The vaccuum expectation values sets the weak energy scale
→ about the mass we would expect for the Higgs boson.

In the pertubative calculation, the Higgs mass receives large radiative corrections up to the cut-off scale Λ, where the SM breaks (eg. the GUT scale, or the Planck scale)

$$m^2 = m_0^2 + (\delta m)^2$$

$$(\delta m)^2 \sim g^2 m^2 / m_W^2 \left(\Lambda^2 - m^2 ln \frac{\Lambda^2}{m^2} + \mathcal{O}\left(\frac{1}{\Lambda^2}\right)\right)$$



vacuum polarization diagram

→ observale Higgs m ~ Λ → This contradicts the EW precision fits!

Theorists can handle this by introducing counter-terms (renormalization),
but these terms have to be extremly fine-tuned in the theory to cancel the divergences:

$$\mathcal{O}(\text{fine tuning}) \approx \frac{\mathcal{O}(EW^2)}{\mathcal{O}(\Lambda^2)} \approx 10^{-26}$$

→ This is neither natural nor convincing.

Why do we need physics Beyond the Standard model?

Other open questions (a few of them)

- **Why is the electrical charge of the proton identical to that of the electron?**
  If it was not true, atoms would not be stable.
  Protons and electrons are very different objects, but are they maybe two sides of the same medal (a new symmetry)? → This is subject to grand unified theories (uniting strong and electroweak interactions)

  More generally, the SM does not explain particle quantum numbers (and, why are there 3 fermion generations, and 3 colors)

- **There are at least 19 free parameters of the SM (forgetting about neutrinos)**
  (9 fermion masses, 3 CKM parameters + 1 weak CP violating phase, 1 strong CP violating phase, three coupling constants, two weak boson masses

  Is it possible to calculate them from first principles?

- A bit more crazy: **What about gravity?** It's a part of our world, can we make it a part of a unified theory as well?

→ The SM agrees well with all experimental data from accelerators, but it is theoretically unsatisfactory

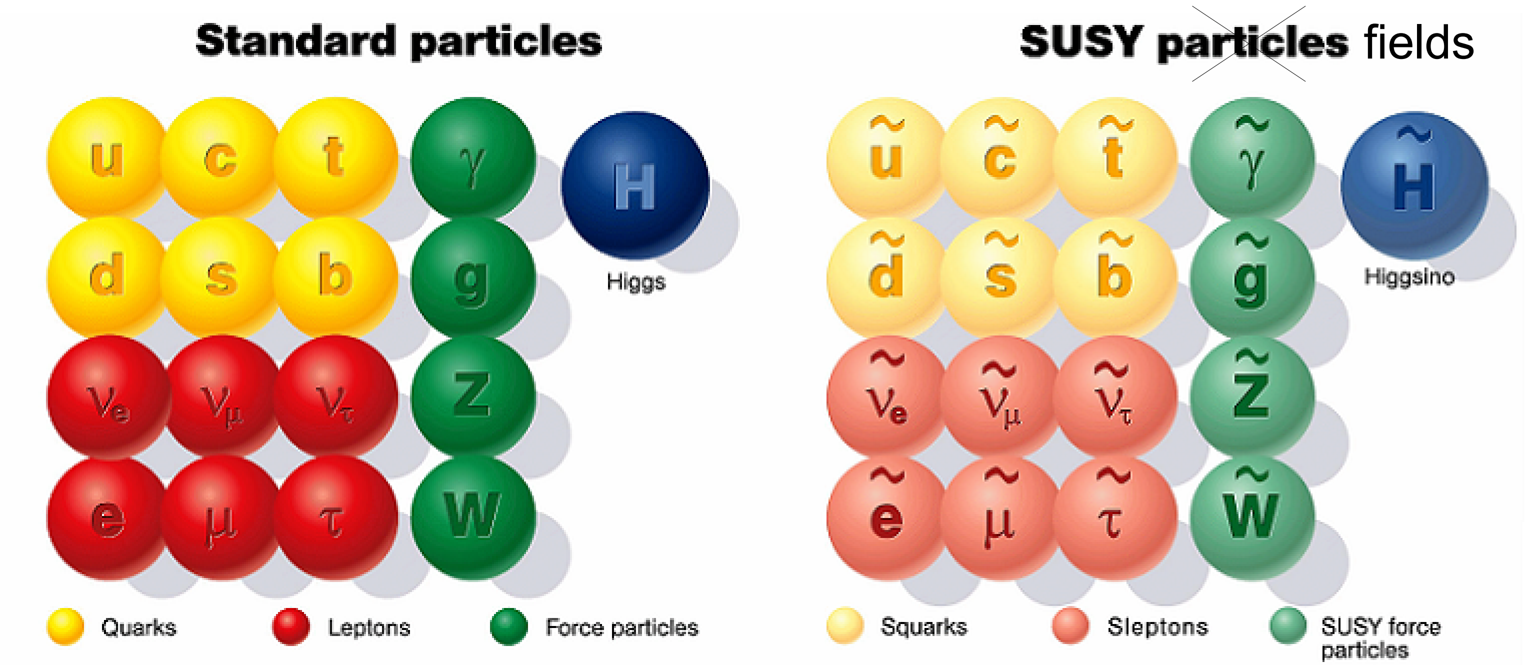
The most-favored extension of the Standard Model: Supersymmetry (SUSY)

SUSY is also part of GUT, string theory, some extra-dimensional models, ...

SUSY is the symmetry transforming bosons into fermions and vice versa:

$$Q|Boson\rangle \propto |Fermion\rangle$$
$$Q|Fermion\rangle \propto |Boson\rangle$$

This predicts a new class of partner particles (in analogy to anti-particles)**:**



The most-favored extension of the Standard Model: Supersymmetry (SUSY)

To increase the confusion...

The SUSY fields mix and then form the **observable SUSY particles**:

Name	Spin	R-parity	Interaction e.s.	Mass e.s.
Higgs bosons	0	+1	H_u, H_d	$h^0, H^0, A^0, H^\pm$
Squarks	0	−1	$\tilde{Q}_{1,2,3},\ \tilde{u}^c, \tilde{c}^c, \tilde{t}^c,\ \tilde{d}^c, \tilde{s}^c, \tilde{b}^c$	$\tilde{u}_{1,2,3,4,5,6},\ \tilde{d}_{1,2,3,4,5,6}$
Sleptons	0	−1	$\tilde{L}_{1,2,3},\ \tilde{e}^c, \tilde{\mu}^c, \tilde{\tau}^c$	$\tilde{\ell}_{1,2,3,4,5,6},\ \tilde{\nu}_{1,2,3}$
Neutralinos	$\frac{1}{2}$	−1	$\tilde{B}^0, \tilde{W}^0, \tilde{H}_u^0, \tilde{H}_d^0$	$\chi^0_{1,2,3,4}$
Charginos	$\frac{1}{2}$	−1	$\tilde{W}^\pm, \tilde{H}_u^+, \tilde{H}_d^-$	$\chi^\pm_{1,2}$
Gluinos	$\frac{1}{2}$	−1	$\tilde{g}$	$\tilde{g}$
Gravitino	$\frac{1}{2}, \frac{3}{2}$	−1	$\tilde{G}$	$\tilde{G}$

Come back to the Higgses in a few slides...

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Gravitino	$\frac{1}{2}, \frac{3}{2}$	−1	$\tilde{G}$	$\tilde{G}$

Come back to the Higgses in a few slides...

So, where are the SUSY particles?

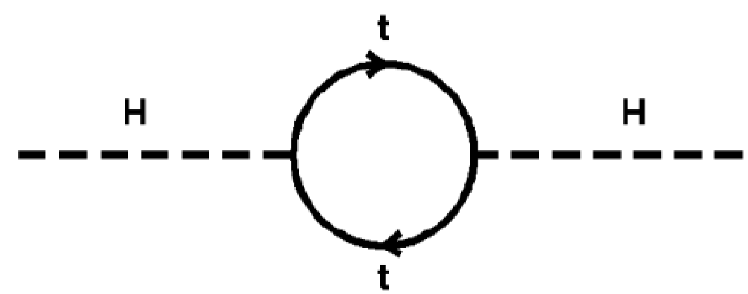
Fact: No SUSY particle has ever been observed *(I will present a few searches later on)*
eg. a boson of 511 keV (the „selectron“) would have probably not escaped our detectors...

→ The SUSY mass scale is higher, SUSY particles are heavier than SM particles
The mass scale is expected to be around 1 TeV.

SUSY is a broken symmetry (it's imperfect). We don't know anything about the breaking mechanism → Our ignorance is parametrized in about 100 new parameters

So, why is SUSY a good theory?

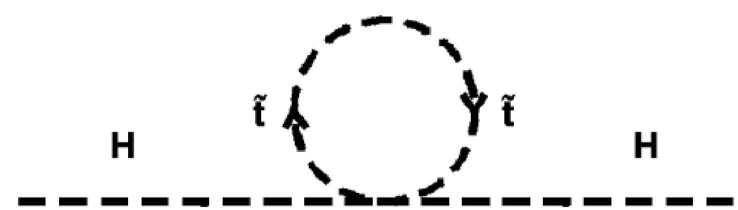
1. It solves the Fine-tuning problem:



$\Delta m_h \sim \Lambda^2$

The sfermion loops cancel the divergent fermion loops:

$$\delta m^2 \approx \mathcal{O}(\alpha) \cdot |m_{\tilde{f}}^2 - m_f^2| \approx \mathcal{O}(10^{-2}) \cdot m_{SUSY}^2$$



$\Delta m_h \sim \ln \Lambda$

The Higgs mass stays small.
This works if m_{SUSY} ~ 1TeV.

So, why is SUSY a good theory? (continued...)

2. It stages a possible dark matter candidate:

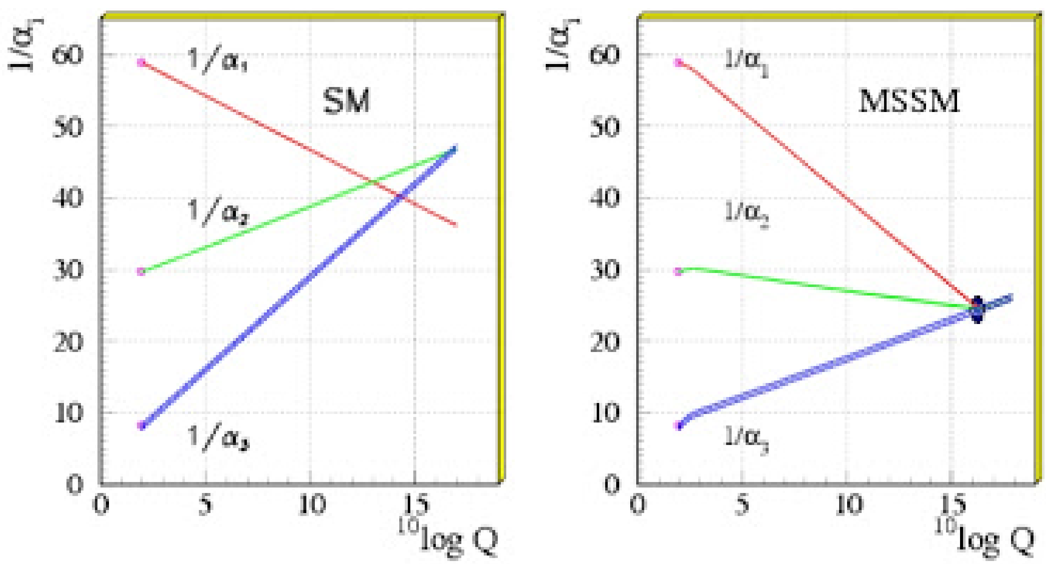
The lightest neutral SUSY particle (the neutralino χ^0) might be stable.
If it is stable it would be a dark matter candidate.

It is stable if R-parity is conserved: $R = (-1)^{2s+3B+L}$

Particles: +1
Sparticles: -1

Conservation of R-parity is elegant because it tells that SUSY particles can only be produced in pairs.

3. It facilitates a grand unification:



The running coupling constants unite at some large energy,

This does not happen in the SM.

However, some theorists argue that this is not always true and that it depends on the details of the SUSY theory eg. breaking parameters

The Higgs Sector in the Minimal SUSY Model: MSSM

$$\begin{pmatrix} u \\ d \end{pmatrix}, \begin{pmatrix} c \\ s \end{pmatrix}, \begin{pmatrix} t \\ b \end{pmatrix}$$

Down-type:
u,d,s, charged leptons

In the SM we introduced one Higgs doublet, now we need two:

$$\Phi = \begin{pmatrix} \Phi^+ \\ \Phi^0 \end{pmatrix} \rightarrow H_u = \begin{pmatrix} h_u^+ \\ h_u^0 \end{pmatrix}, \; H_d = \begin{pmatrix} h_d^0 \\ h_d^- \end{pmatrix}$$

H_u couples to up-type fermions
H_d couples to down-type fermions

→ Two vev's: v_u, v_d

In the SM we had 4 degrees of freedom, now we have 8.
3 of them are absorbed as masses into the Z and $W^\pm$ bosons, 5 remain.

→ Five detectable Higgs bosons: **h**, **H**, **A**, H^+, H^-

- h: Light CP Even Higgs
- H: Heavy CP even Higgs
- A: CP-odd Higgs (pseudo scalar)
- H^+, H^-: Charged Higgs

On tree level, the whole Higgs sector can be described with just 2 parameters:

$\mathbf{m_A}$ Coupling parameter $\mathbf{\tan\beta} = v_u / v_d$

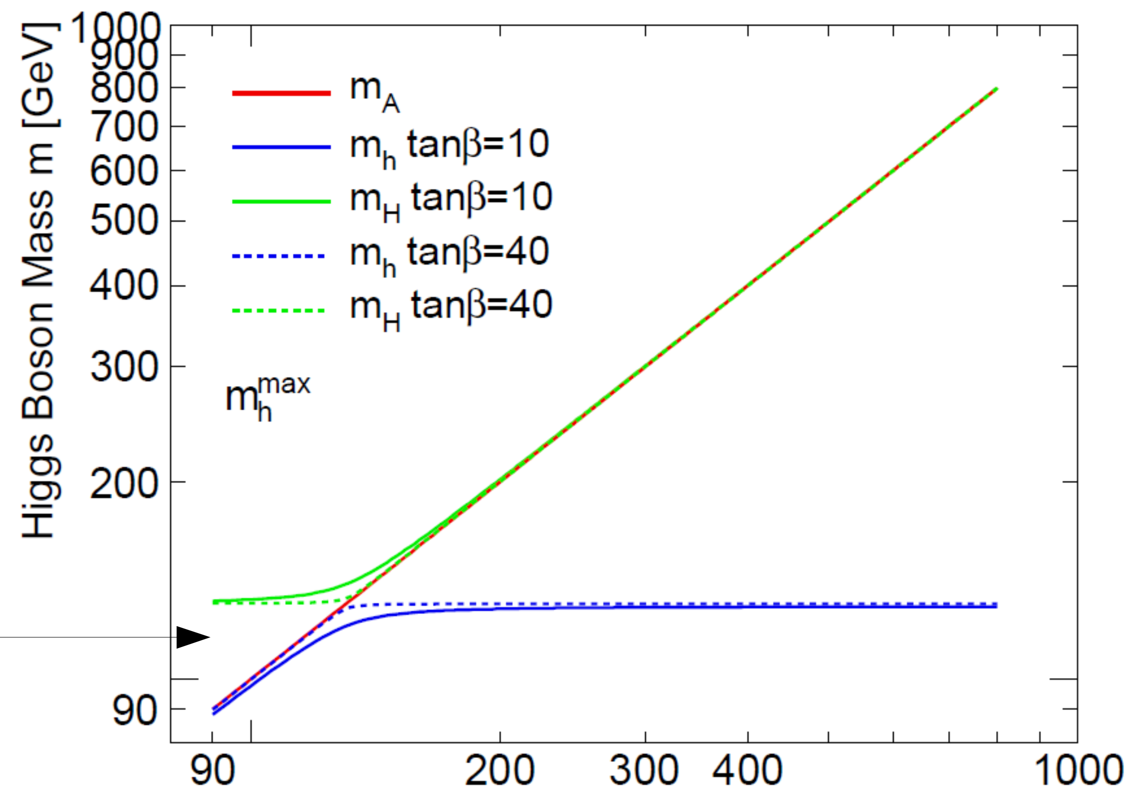
The Higgs Sector in the Minimal SUSY Model: MSSM

Remarkable: The mass of the lighest Higgs is constrained

$$m_h \; < \; m_Z \cos 2\beta + \Delta$$ ← SUSY enters

Δ is a term for radiative corrections from stop loops, details are model-dependent.
Usually it is assumed that $m_h \leq 130$ GeV
(130 GeV is quite large already, lesser would be more appreciated by theorists)

Masses of the neutral Higgs bosons as a function of m_A and $\tan\beta$:



The light SUSY Higgs h is always light.

The discovery of a heavy Higgs would be strong evidence for SUSY.

The Higgs Sector in the Minimal SUSY Model: MSSM

How do $h/A/H/H^{\pm}$ relate to the SM Higgs?

- **„Decoupling limit“ $m_A >> m_Z$**

  h is SM-like (not exactly identical), $H/A/H^{\pm}$ are very heavy

- **„Anti-decoupling limit“ $m_A \approx m_Z$, tanβ large**

  H **is** the SM Higgs, $h/A/H^{\pm}$ are light

- **„intermediate-coupling regime“ $m_A \geq m_Z$, moderate tanβ**

  Neither SUSY Higgs is SM-like

The Higgs Sector in the Minimal SUSY Model: MSSM

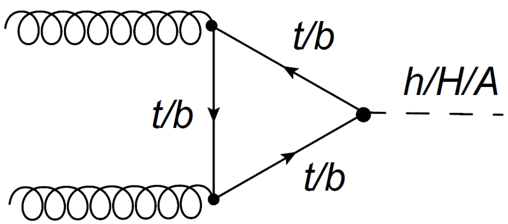
In the MSSM, the couplings of Higgs bosons to other particles are different to those in the SM.

→ Modified cross sections and branching ratios → Different search channels

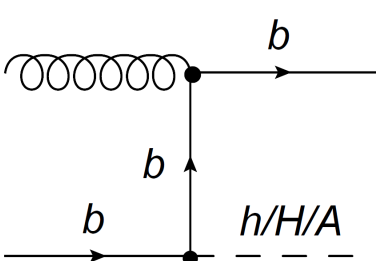
In particular: The coupling to down-type fermions is enhanced, depending on tanβ.

→ Larger probability for decay into ττ and μμ, and also to $b\bar{b}$.

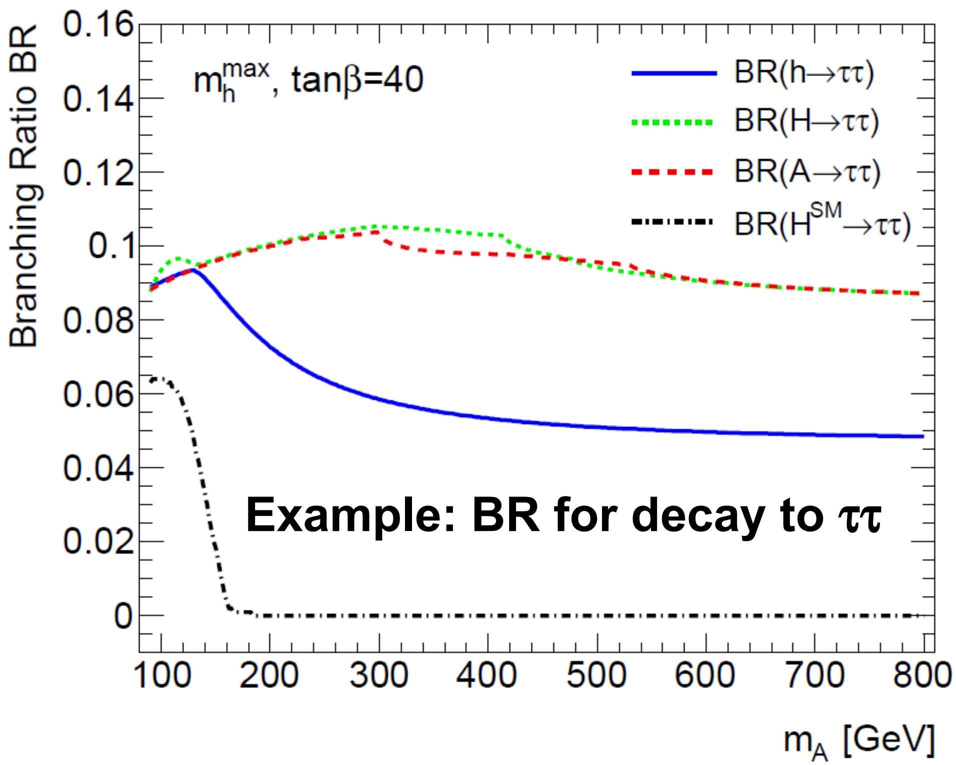
The decay to H → VV (V=Z/W) is supressed, and A → VV is not allowed



Gluon fusion enhanced for large tanβ



b-associated production is very important



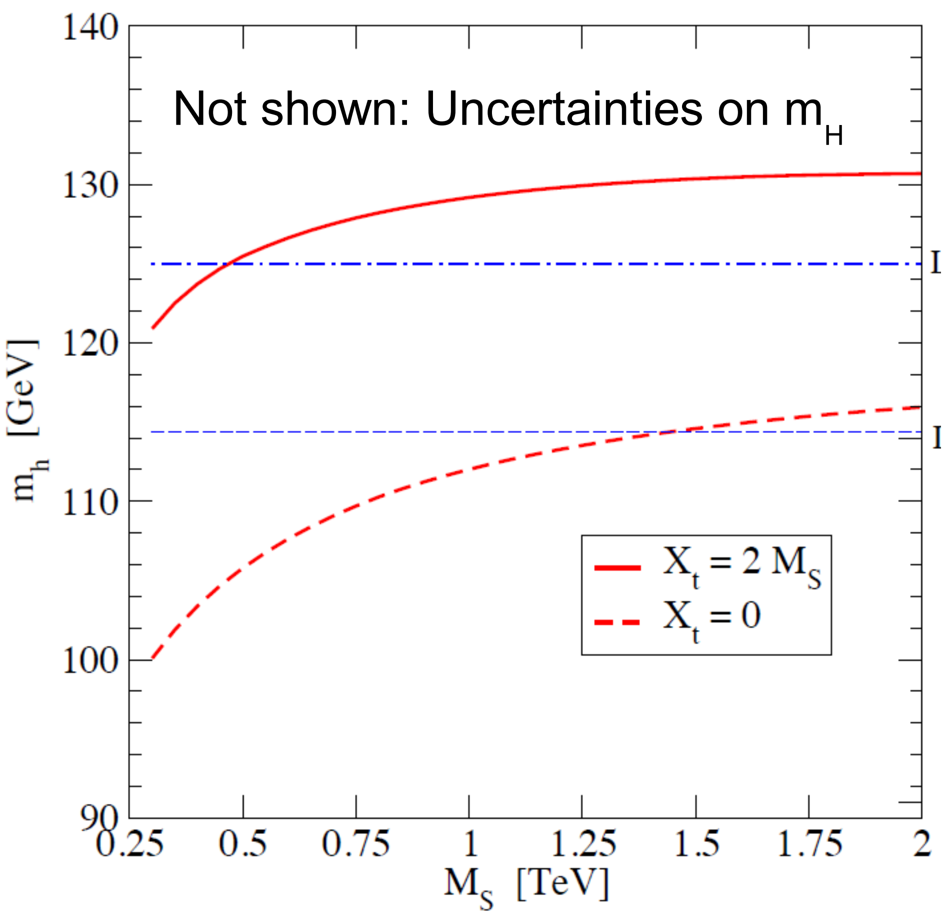
→ THAT's WHY WE NEED TO MEASURE COUPLINGS OF THE NEW PARTICLE at 125 GeV

What can we learn from a Higgs at 125 GeV?

Let's assume the new particle is a SUSY Higgs. It's mass depends on SUSY:

$$m_h < m_Z \cos 2\beta + \Delta$$

Δ is mostly influenced by the stop sector. Important parameters:



$M_S=\sqrt{(m_{\tilde{t}1} * m_{\tilde{t}2})}$ (SUSY mass scale, stop mass)

$X_t=A_t-\mu\cot\beta$ (stop mixing parameter)

For that plot other parameters fixed:

$$\mu = M_2 = 200 \text{ GeV}, \quad m_{\tilde{g}} = 0.8\, M_S,$$

$$m_A = 500 \text{ GeV}, \quad \tan\beta = 10$$

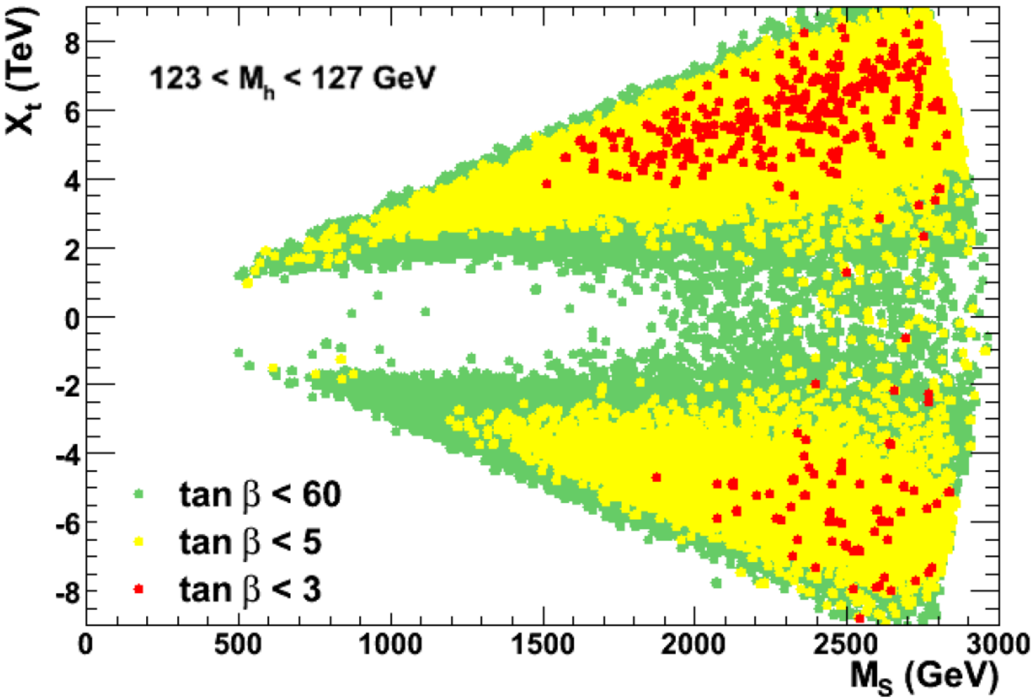
Plot: Pietro Slavich (LPTHE Paris) using Feynhiggs

What can we learn from a Higgs at 125 GeV?

Consider the „Phenomenological MSSM“ (pMSSM)

No special assumptions of SUSY breaking, but SUSY parameter range simplified and reduced to 22 parameters (pMSSM details: arXiv:1109.3859v3)

Result of a parameter scan: (arXiv:1112.3028v3)



No experimental data taken into acount except for m_H.

Each point represents one set of parameter values that give the correct (observed) Higgs mass.

Scan range:

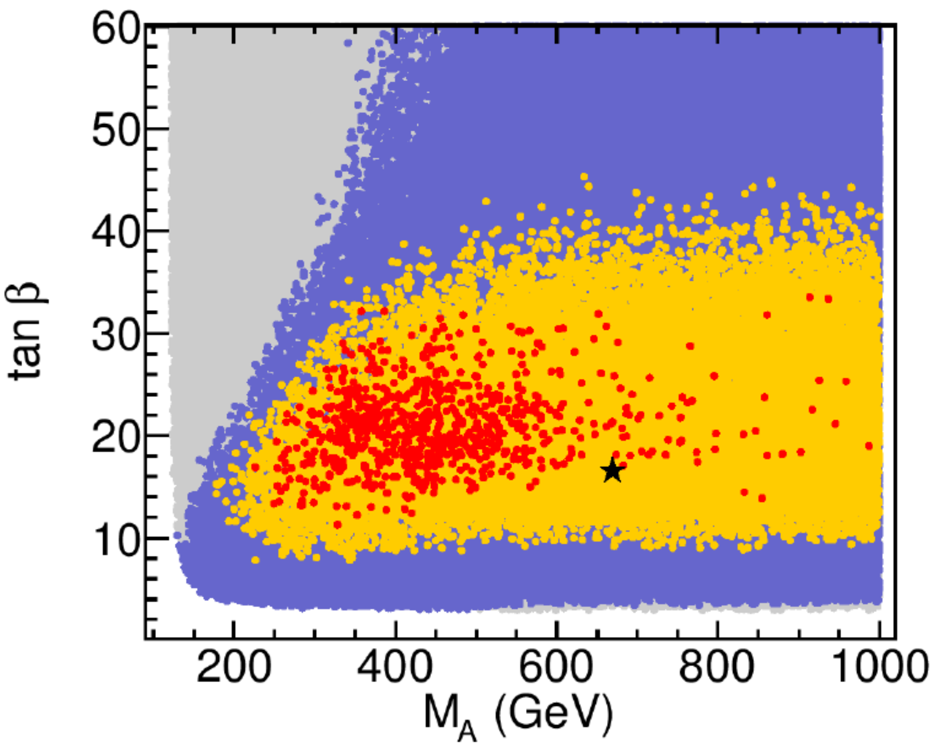
$$1 \leq \tan\beta \leq 60\,,\ 50\ \mathrm{GeV} \leq M_A \leq 3\ \mathrm{TeV}\,,\ -9\ \mathrm{TeV} \leq A_f \leq 9\ \mathrm{TeV}$$
$$50\ \mathrm{GeV} \leq m_{\tilde f_L}, m_{\tilde f_R}, M_3 \leq 3\ \mathrm{TeV}\,,\ 50\ \mathrm{GeV} \leq M_1, M_2, |\mu| \leq 1.5\ \mathrm{TeV}$$

What can we learn from a Higgs at 125 GeV?

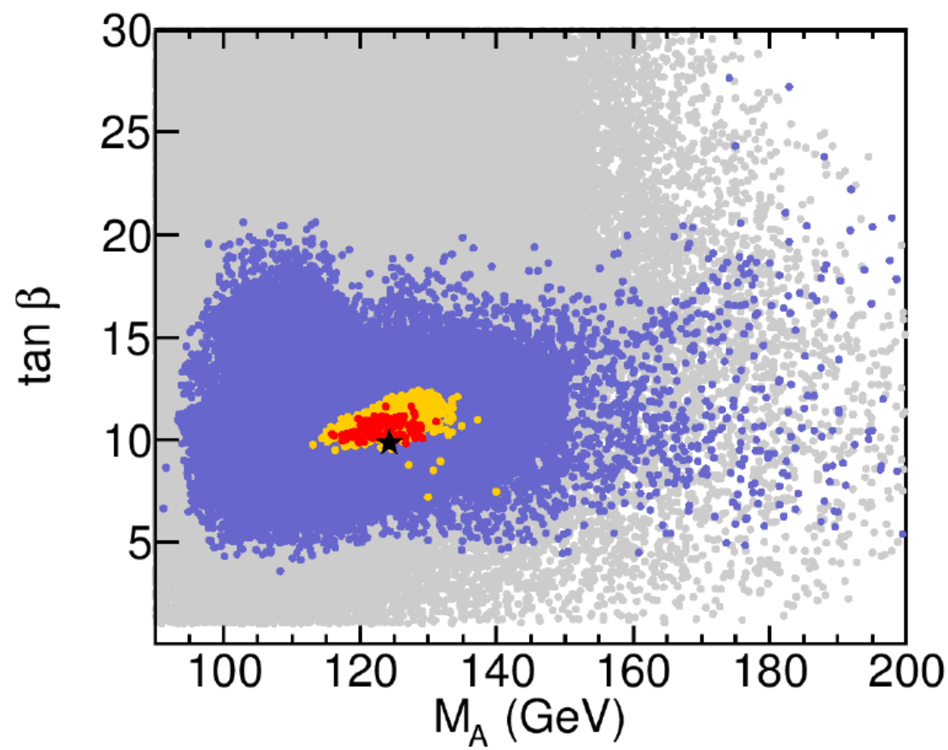
Another paper does a scan in pMSSM with 7 free parameters: arXiv:1211.1955v1

This scan takes also into account the signal strengths of Higgs searches in ATLAS & CMS + low energy observables (eg. b→sγ, g-2) and quantifies the agreement of data and model:

New particle is light CP-even Higgs h:



New particle is heavy CP-even Higgs H:



Each point represents one model which would be allowed, color quantifies the fit quality.

→ **The new particle could either be h or H**, both options are possible. If it is H, than h/A would be light. If it was h, than H/A would be heavy.

Search for BSM Higgs at the LHC

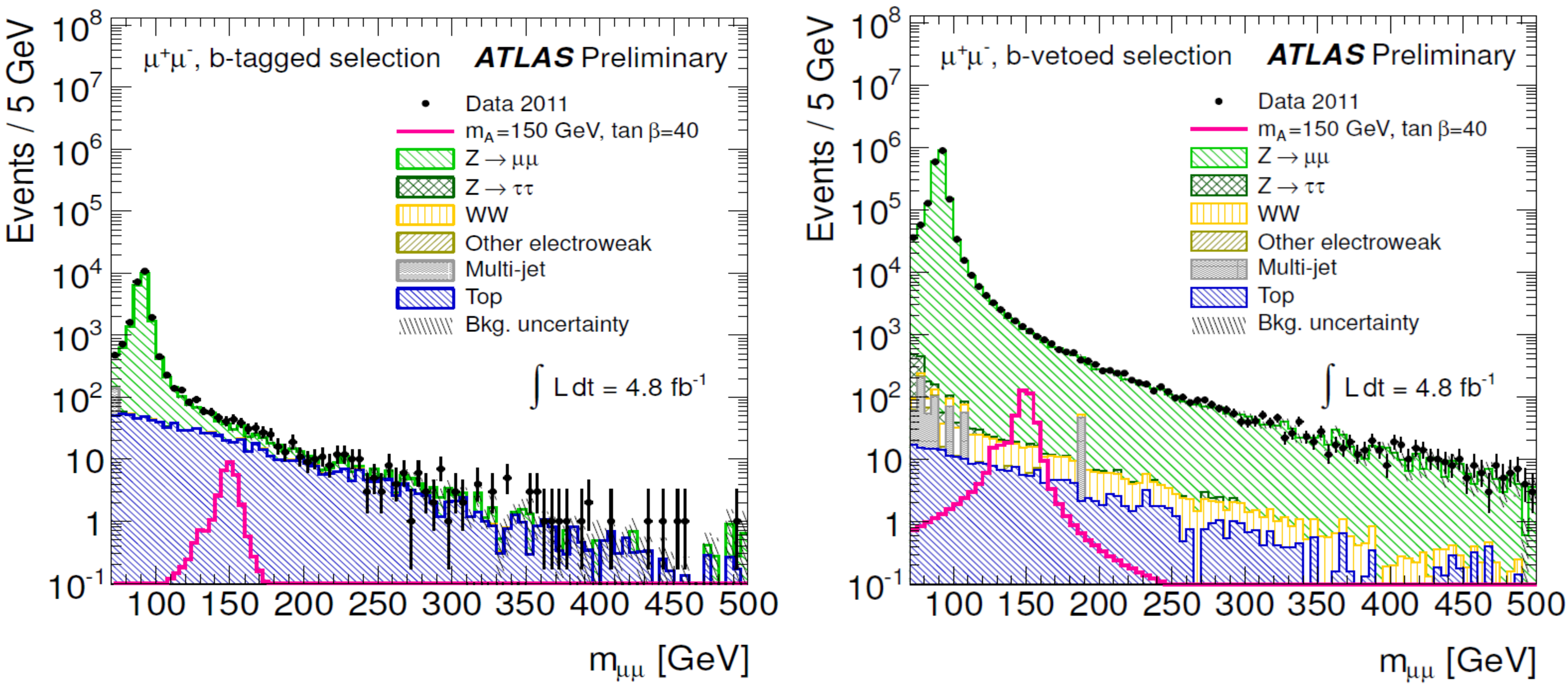
(selection)

Searches for BSM Higgs: Neutral MSSM Higgs

h/A/H → μμ

This decay has a branching ratio of only 0.04%, but similar to $H \rightarrow \gamma\gamma$ it is a clear final state and the background can be estimated with a fit to the dimuon mass.

Analysis is split into b-tagged category (sensitive to b-associated Higgs) and b-vetoed category (sensitive to gluon fusion production).

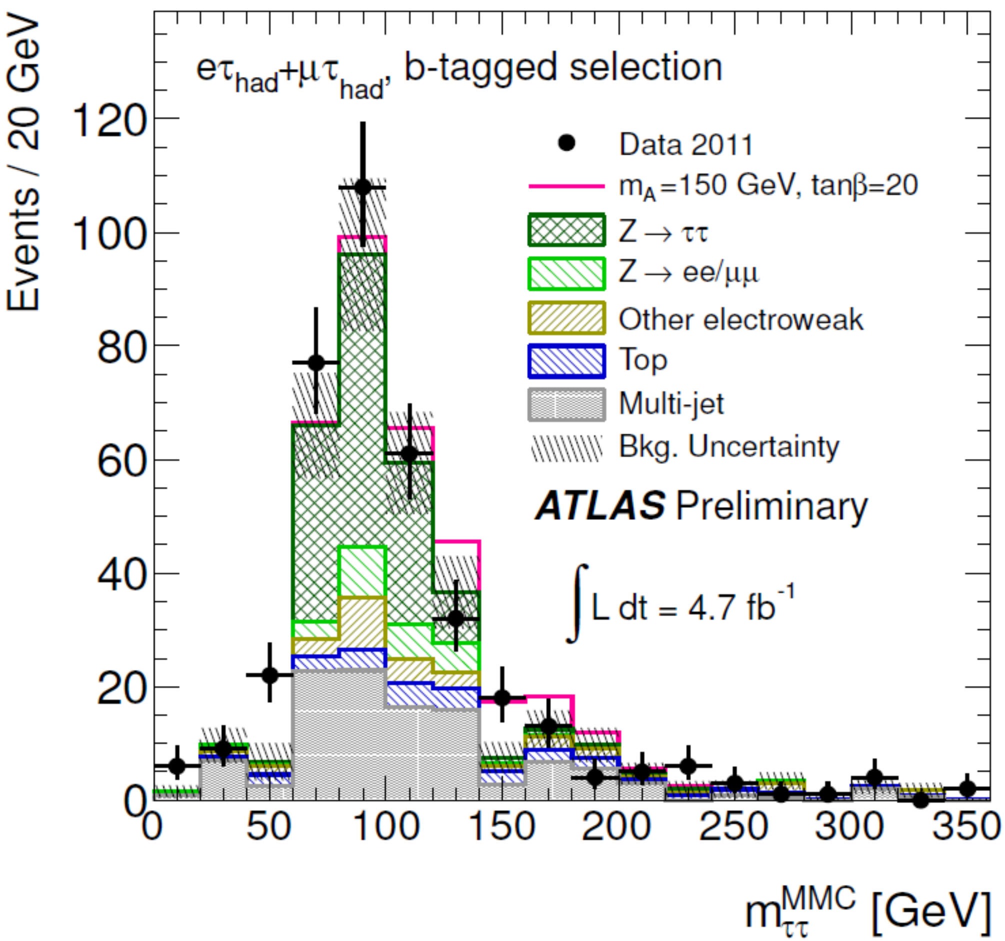


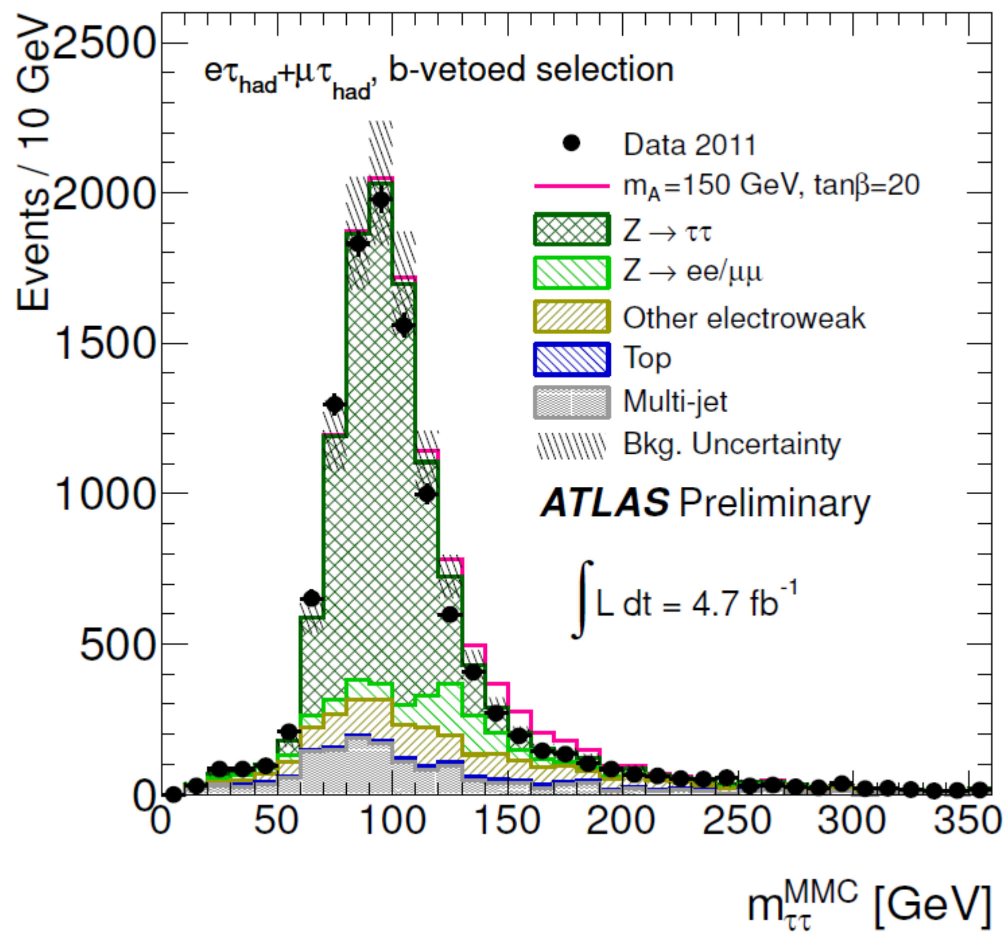
→ **No excess observed!**

Searches for BSM Higgs: Neutral MSSM Higgs

h/A/H → ττ

Again, analysis split into b-tagged and b-vetoed categories.
Leplep, lephad and hadhad channels considered.
Just like in the SM search, $Z \to \tau\tau$ is the dominant background.

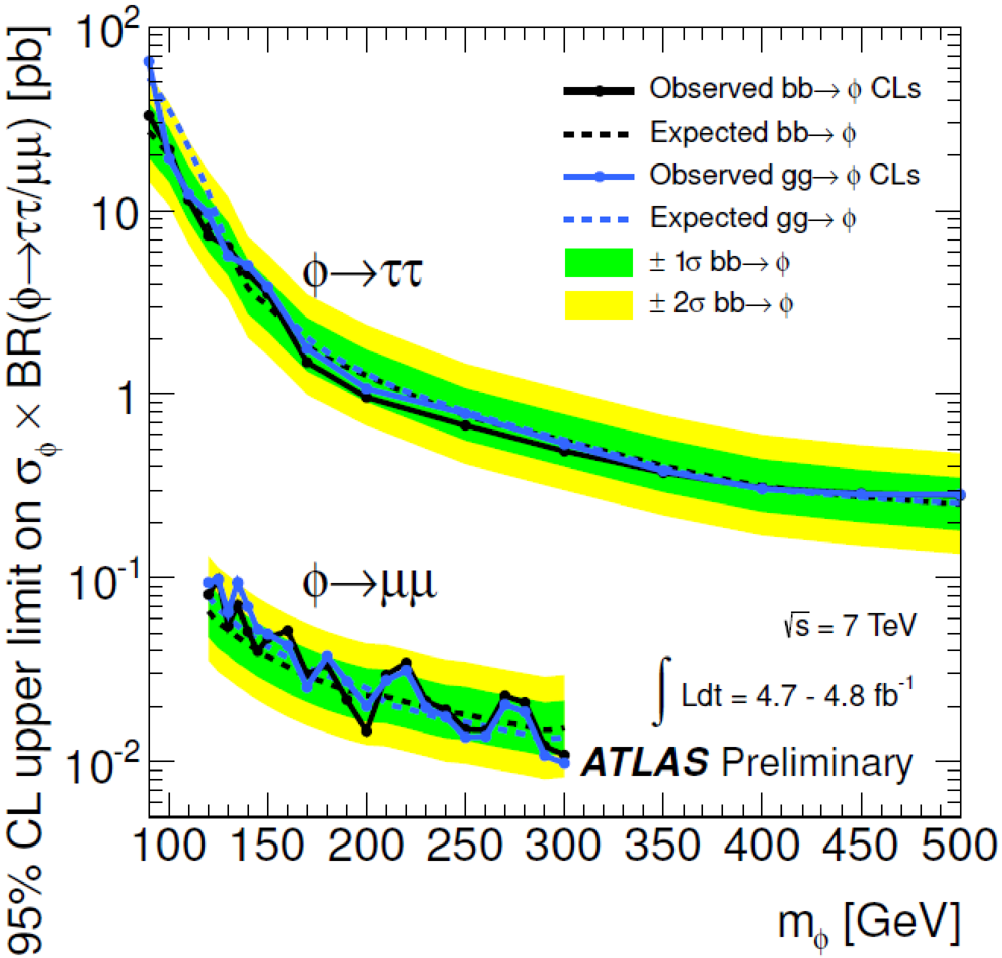




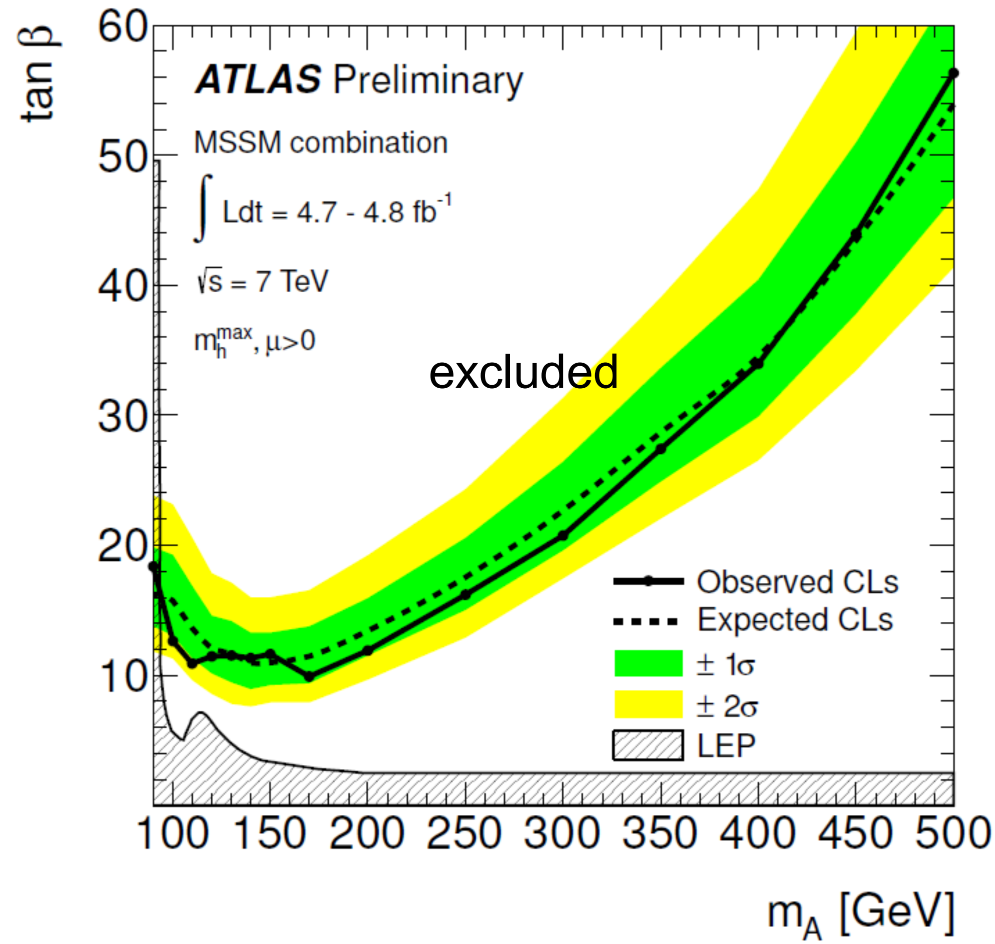
→ No excess observed!

Searches for BSM Higgs: Neutral MSSM Higgs

Limits on cross section:



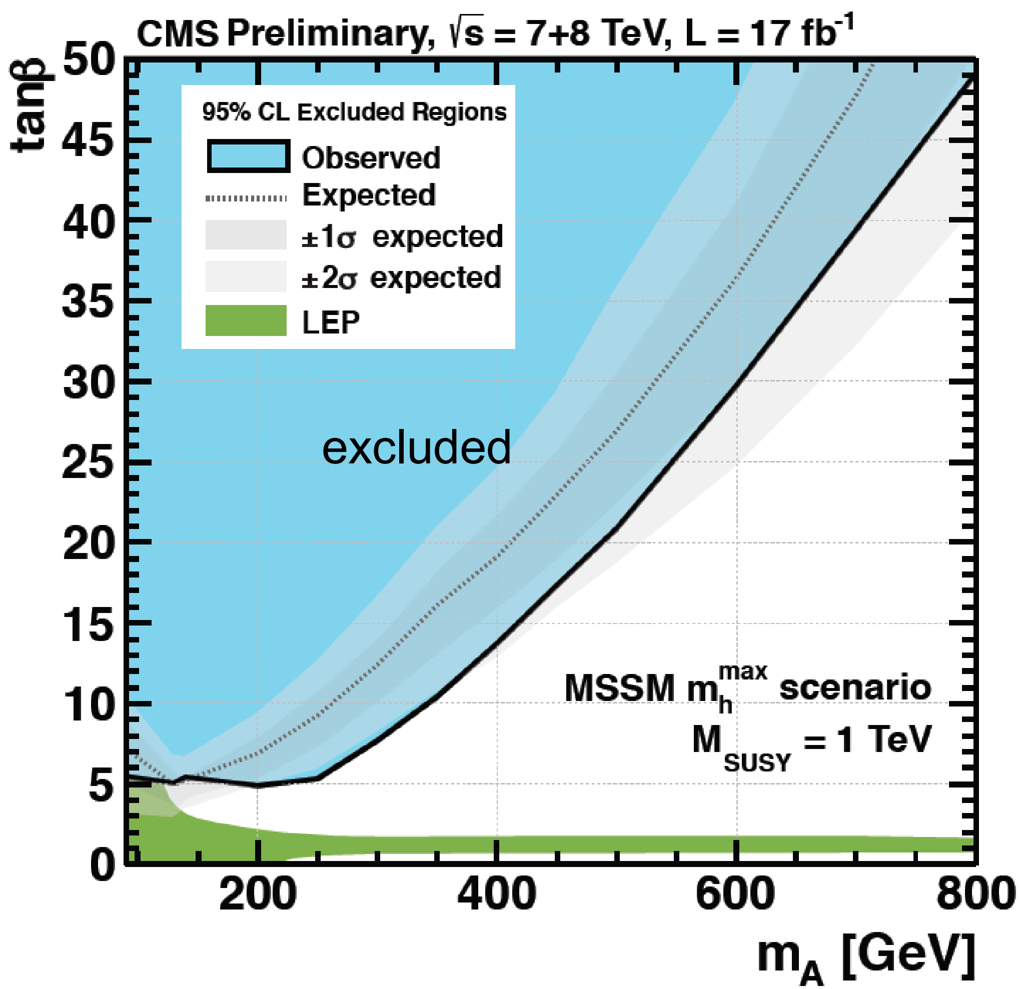
Limits on parameters:

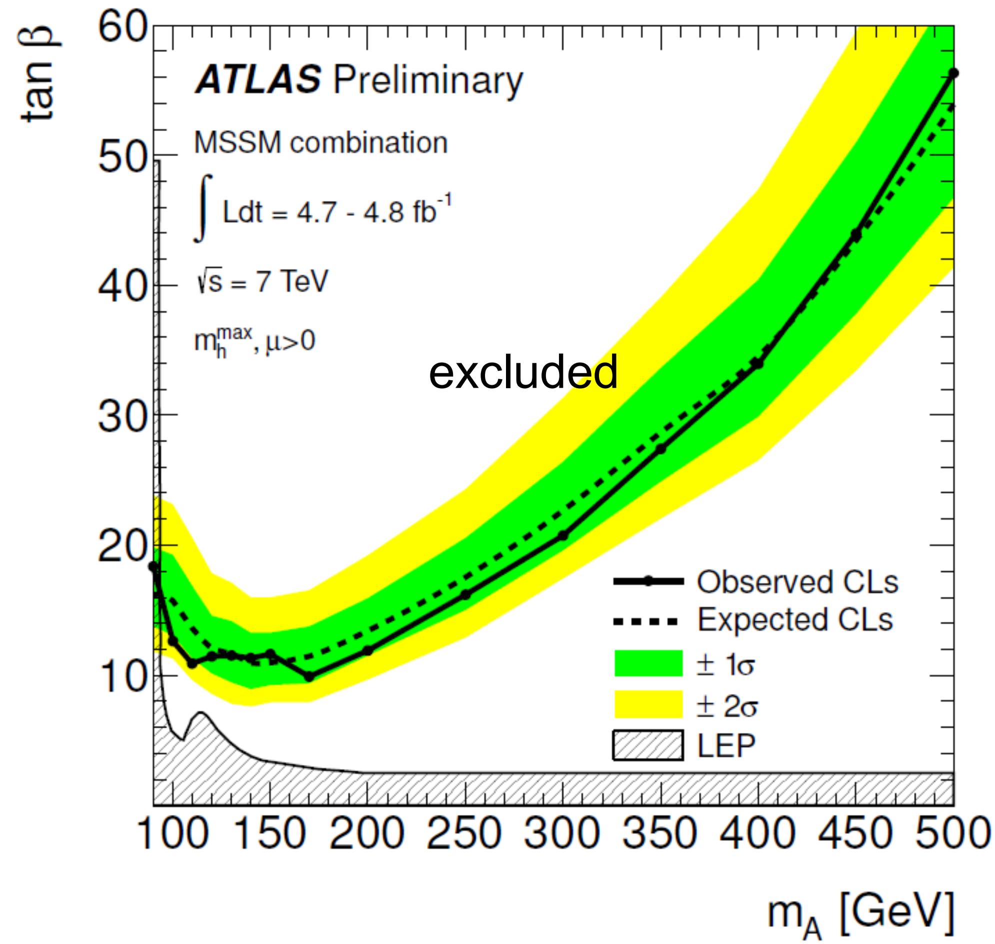


→ **No excess observed!**

Searches for BSM Higgs: Neutral MSSM Higgs

CMS vs ATLAS:

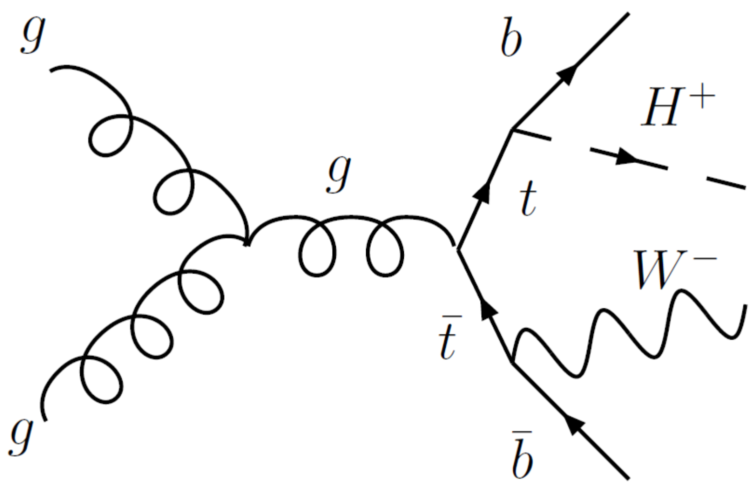


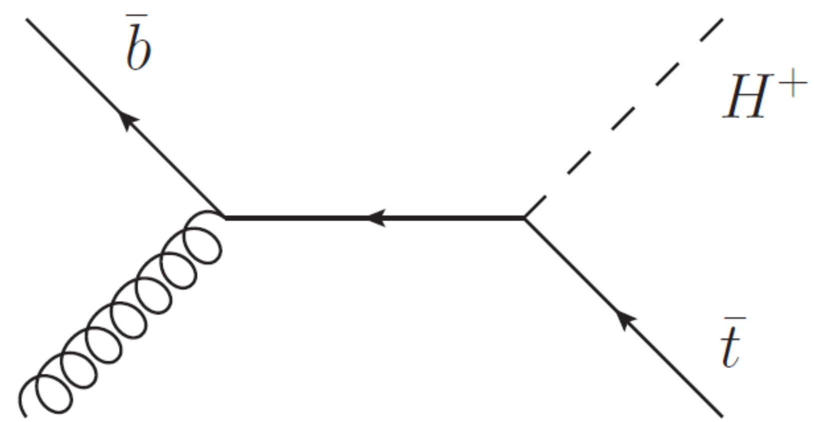


→ **No excess observed!**

Searches for BSM Higgs: Charged MSSM Higgs

Charged Higgs production depends on charged Higgs mass:





If $m_H < m_t$:

$t \to H^+ b$

($H^\pm$ produced in top decay)

Dominant decay:
$H^+ \to \tau\nu$

(dominant for tanβ > 3)

If $m_H > m_t$:

$gb \to tH^+$ (or $gg \to tbH$)

($H^\pm$ produced in gluon-bottom fusion)

Dominant decays:
$H^+ \to \tau b$ and $H^+ \to \tau\nu$

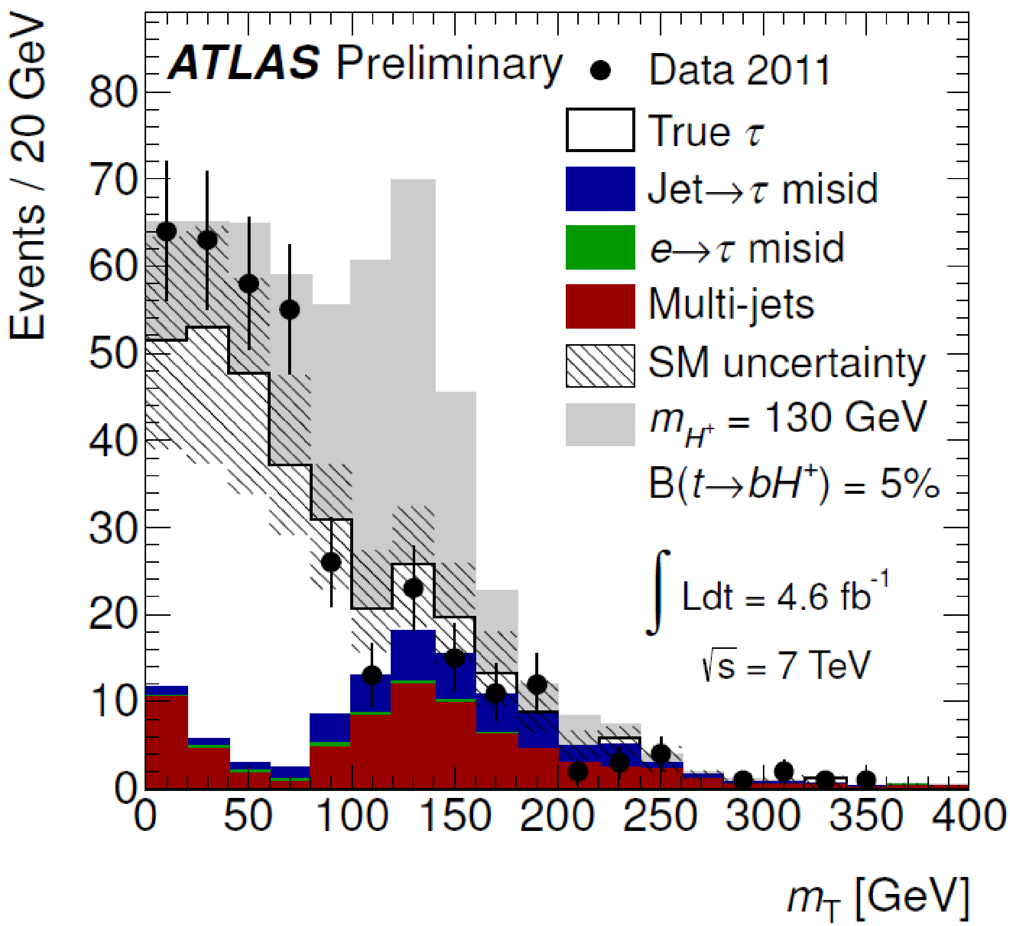
Searches for BSM Higgs: Charged MSSM Higgs

ATLAS search for tt → bbWH$^+$ with H$^+$ → τν

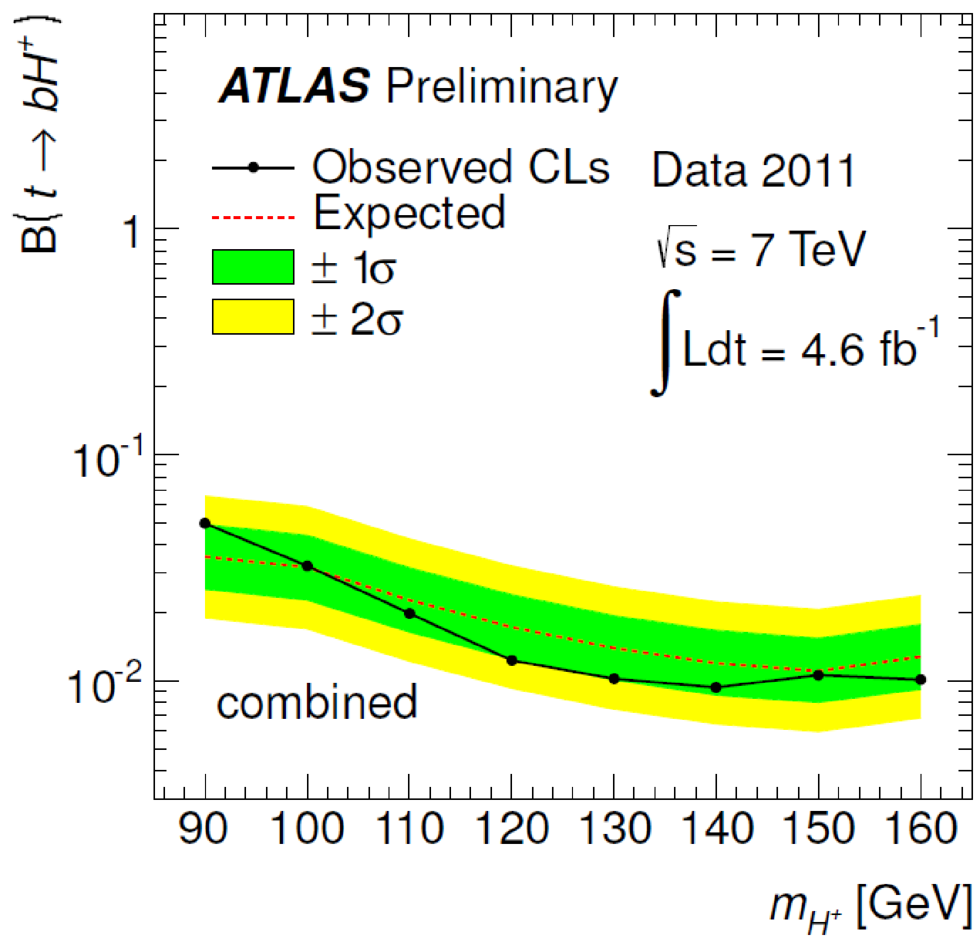
Assuming BR(H$^+$ → τν) = 100%

Leptonic and hadronic tau decays considered, W decay to leptons or quarks.

Example channel: $t\bar{t}$ → $b\bar{b}$WH$^+$ → $b\bar{b}$(qq')τν



Combined:



→ **No excess observed!**

NMSSM: Next-to-Minimal SUSY Extension of the SM

In the MSSM, the Higgs potential parameter μ has the dimension of a mass and in order that the theory works, it must have a value of 0.1-1 TeV.
→ We would like to get rid of a-priori assumptions on parameters

Introduce a new Higgs singlet superfield S in addition to the MSSM Higgs doubletts:

$$\hat{S},\ \hat{H}_d = \begin{pmatrix} \hat{H}_d^0 \\ \hat{H}_d^- \end{pmatrix},\ \hat{H}_u = \begin{pmatrix} \hat{H}_u^+ \\ \hat{H}_u^0 \end{pmatrix}$$

→ (Even) more Higgs bosons observable (now there are 7):

3 scalars H_1,H_2,H_3
2 pseudo-scalars a_1,a_2 → usually the a_1 is very light
2 charged Higgs $H^\pm$

For more information, here are two reviews on the NMSSM:

arXiv:0910.1785 [hep-ph]

www.physics.gla.ac.uk/~dmiller/doc/nmssm_review.ps

NMSSM: Next-to-Minimal SUSY Extension of the SM

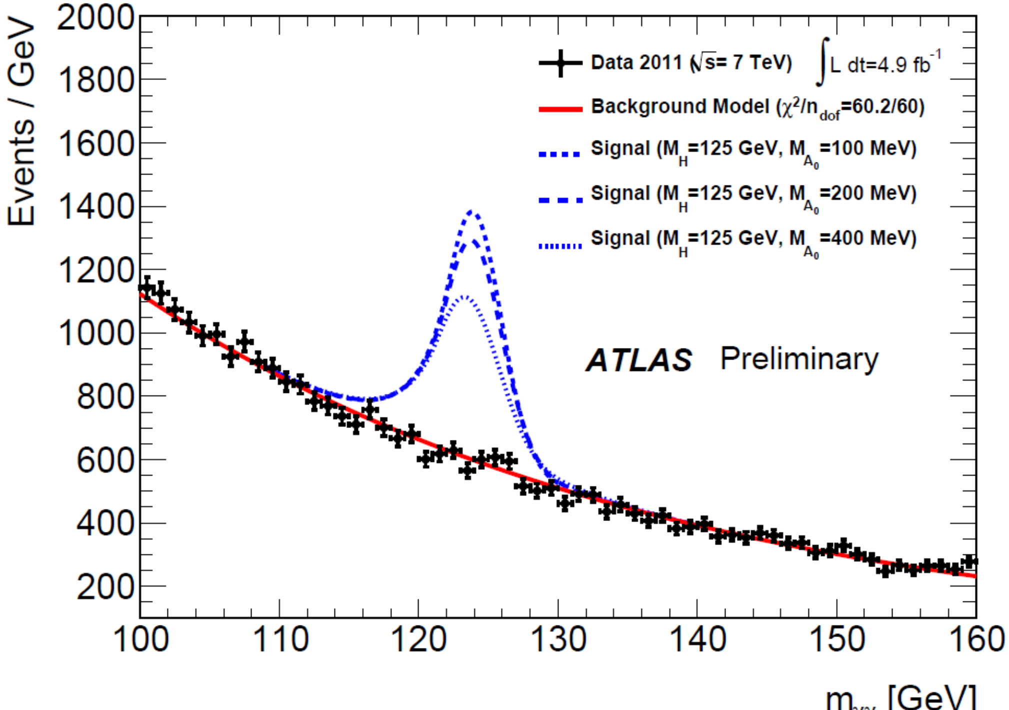
ATLAS Search for Higgs decay to low-mass pseudoscalar a^0 (100-400 MeV)

If $\mathbf{a^0}$ mass below $3{*}\pi^0$ mass, then the dominant decay is $\mathbf{a^0} \rightarrow \gamma\gamma$

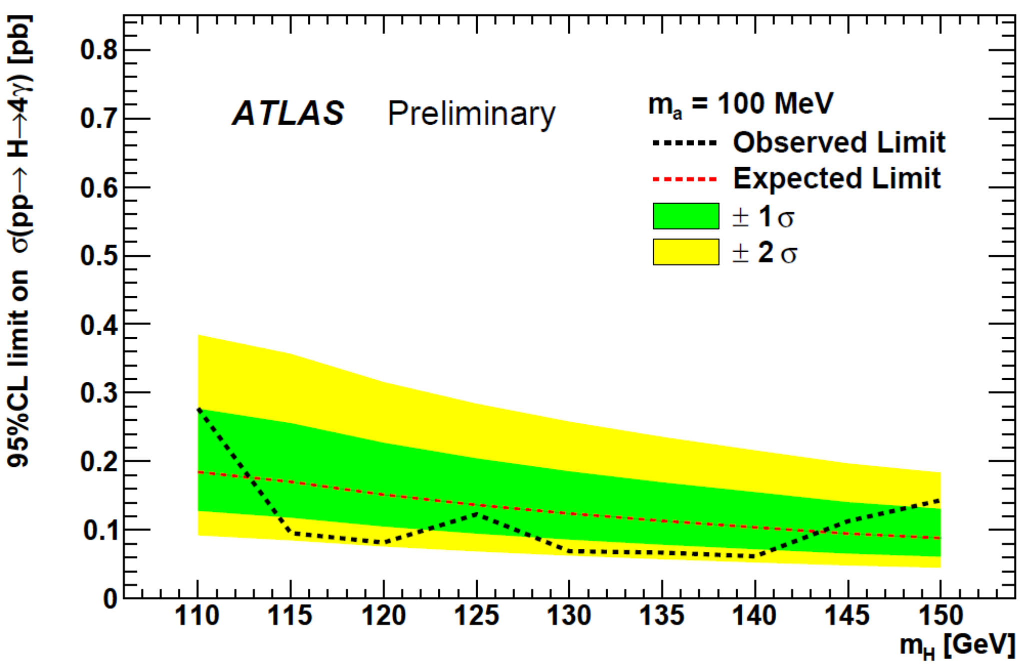
Consider the decay $\mathbf{H \rightarrow a^0 a^0 \rightarrow \gamma\gamma + \gamma\gamma}$
H does not need to be specified further, the aim is to set a limit on its cross section

The a_0 are extremely forward → Each $\gamma\gamma$ pair appear as one cluster
→ The experimental difficulty of this analysis was to refine the photon ID

Diphoton mass:



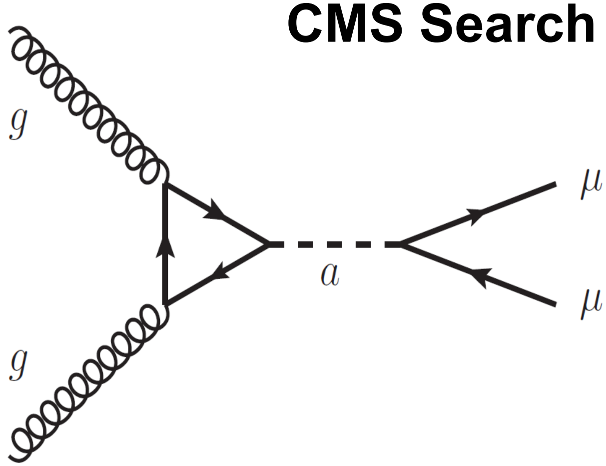
Limit on the cross section:



→ No excess observed!

NMSSM: Next-to-Minimal SUSY Extension of the SM

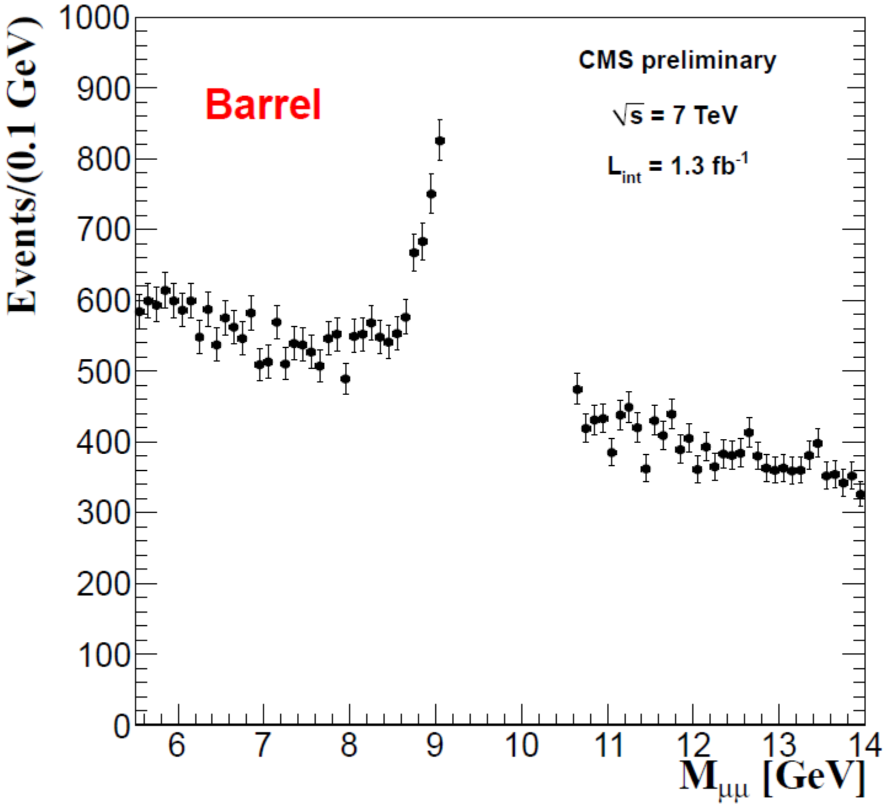
CMS Search for a light pseudo-scalor $a^0 \to \mu\mu$

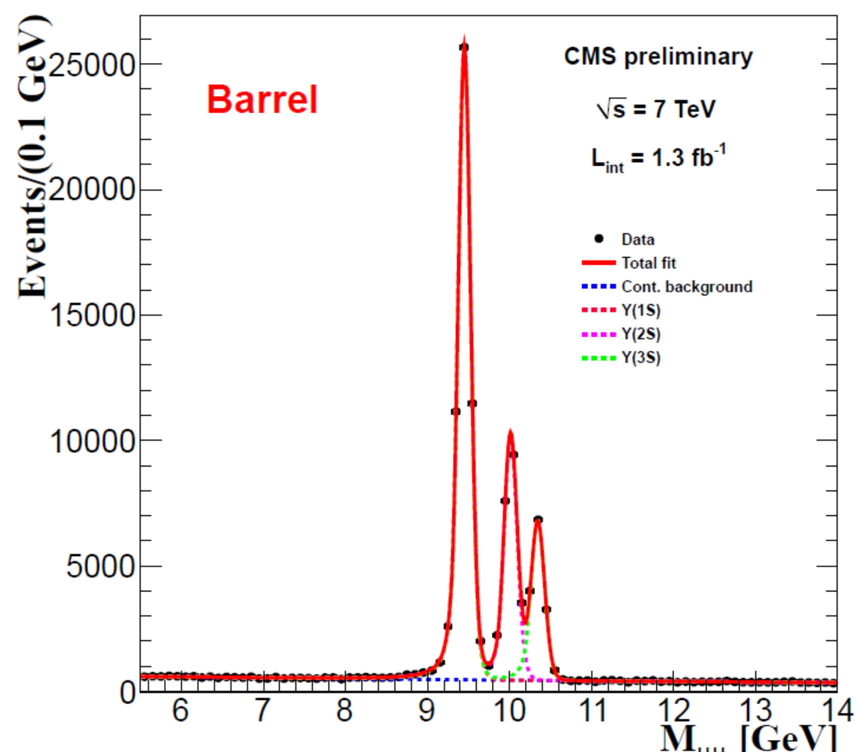


Could be produced with very large cross sections eg. $\tan\beta=30$ $\sigma=10^6$ pb, or $\tan\beta=2$ $\sigma=10^4$ pb

→ even if decay $a \to \mu\mu$ is rare, large signal expected.
→ Look for a dimuon resonance!

Overwhelming backgrounds from $\Upsilon \to \mu\mu$ resonances
→ Cut them out from the search region





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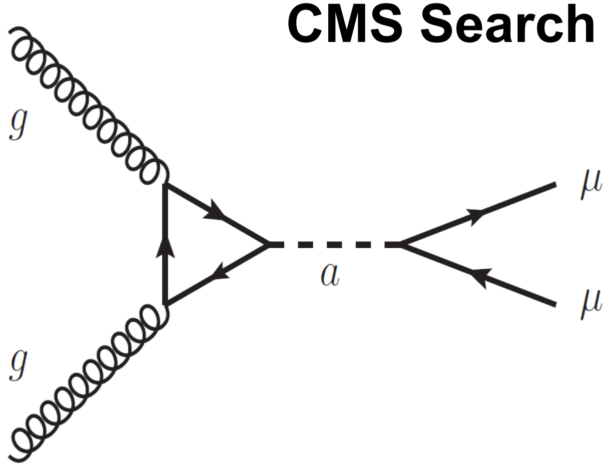
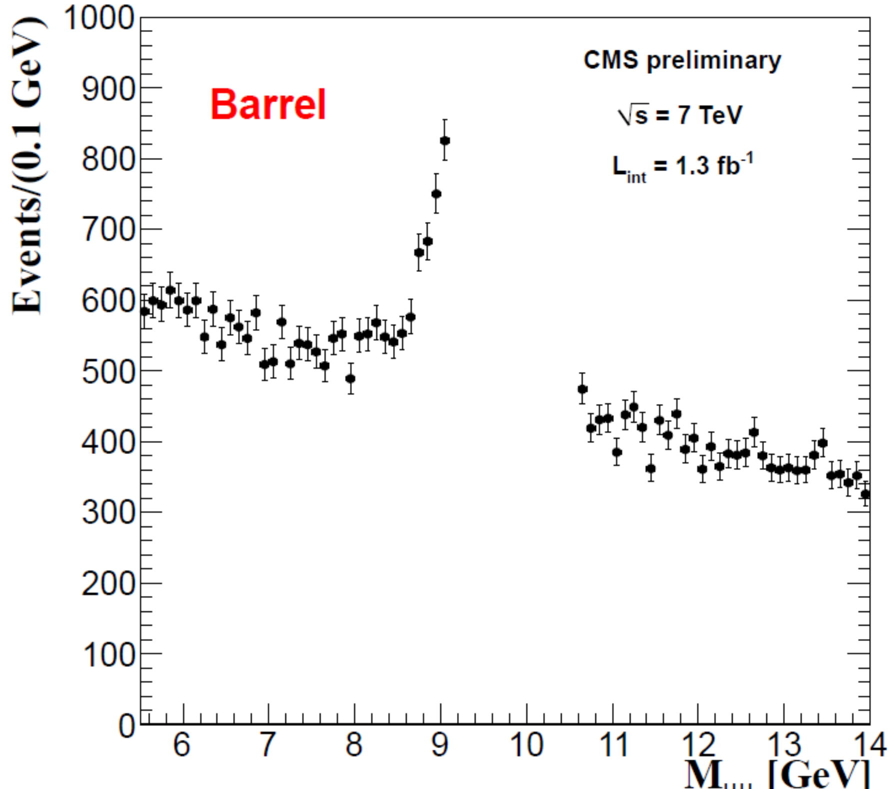
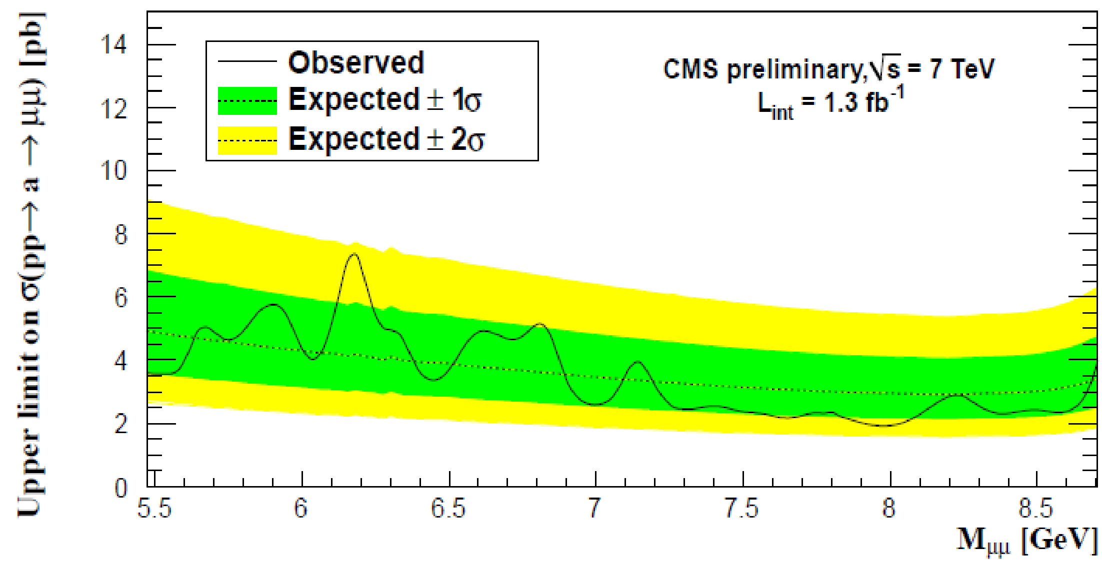
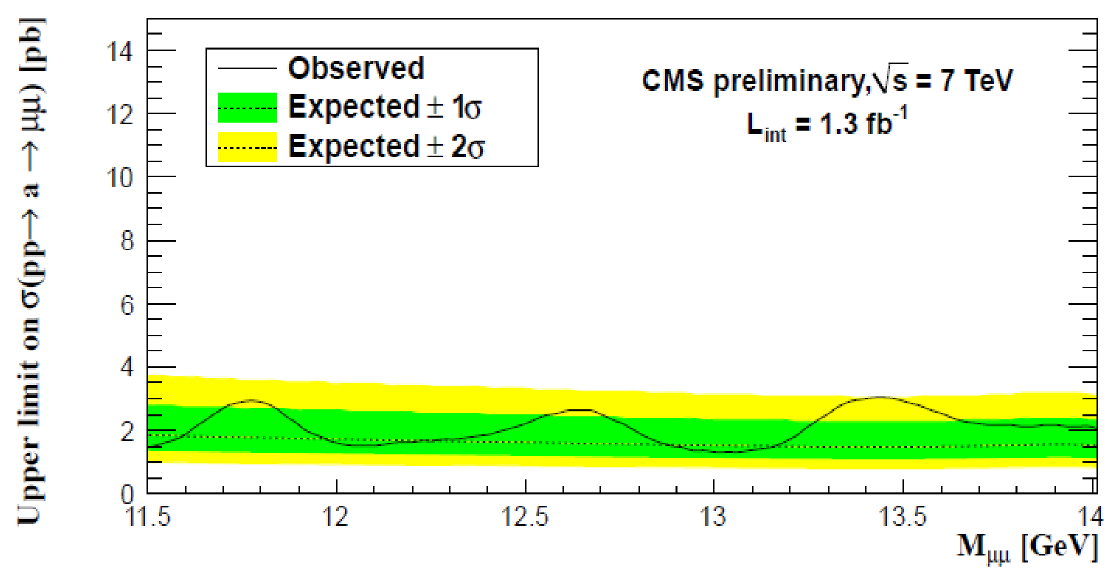
NMSSM: Next-to-Minimal SUSY Extension of the SM

CMS Search for a light pseudo-scalor $a^0 \rightarrow \mu\mu$



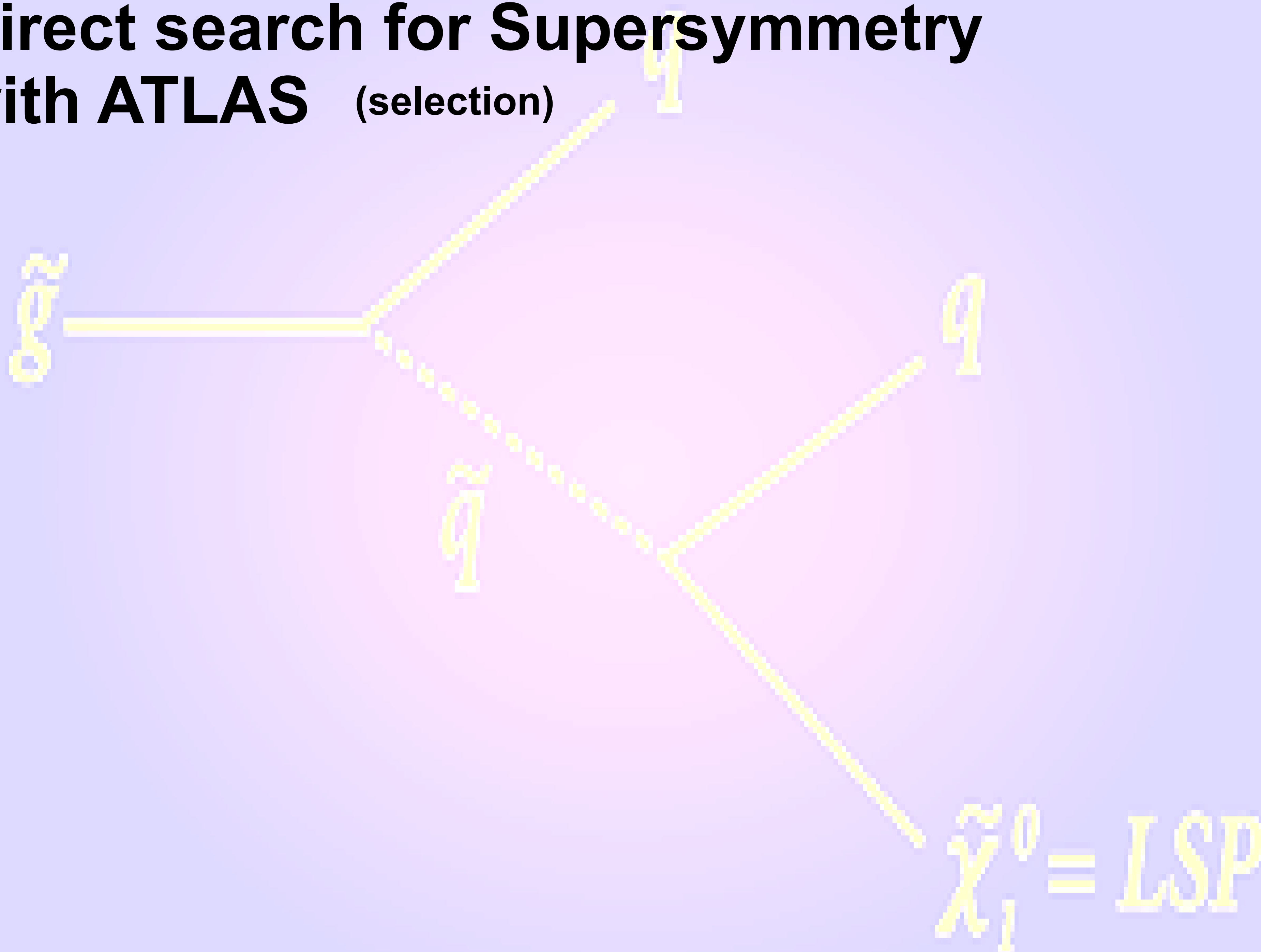






$\rightarrow$ **No excess observed!**

Direct search for Supersymmetry with ATLAS (selection)

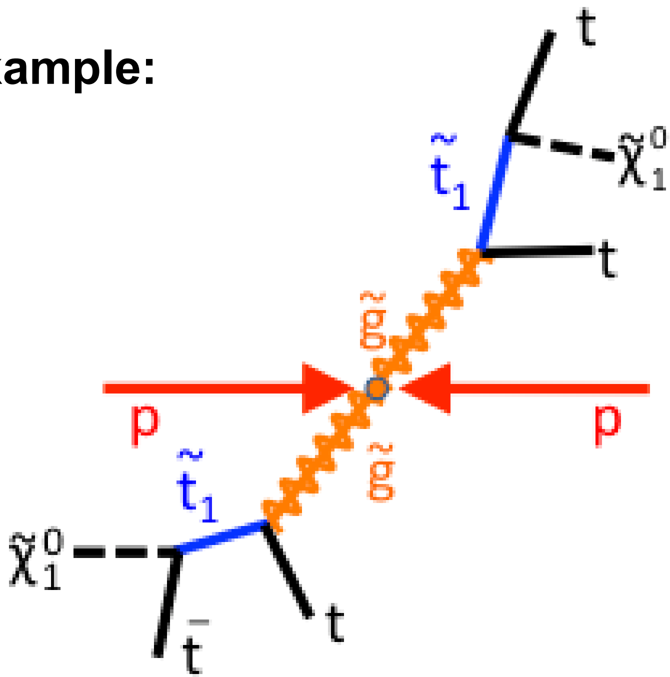


Search for SUSY particles

ATLAS-CONF-2012-145

ATLAS search for gluino pairs, eg. in final states with ≥ 3 b-jets and MET

Example:



LSP is long-lived.
$\tilde{t}_1$ and $\tilde{b}_1$ are light and are produced with a high rate.

Discriminating variables:

- Large MET
- large m_{eff}
- >=4 or 6 jets of with at least 3 are b-jets
- large pT of the b-jets

Remember: t → Wb with almost 100%.
So there are many true b-jets in the final state.

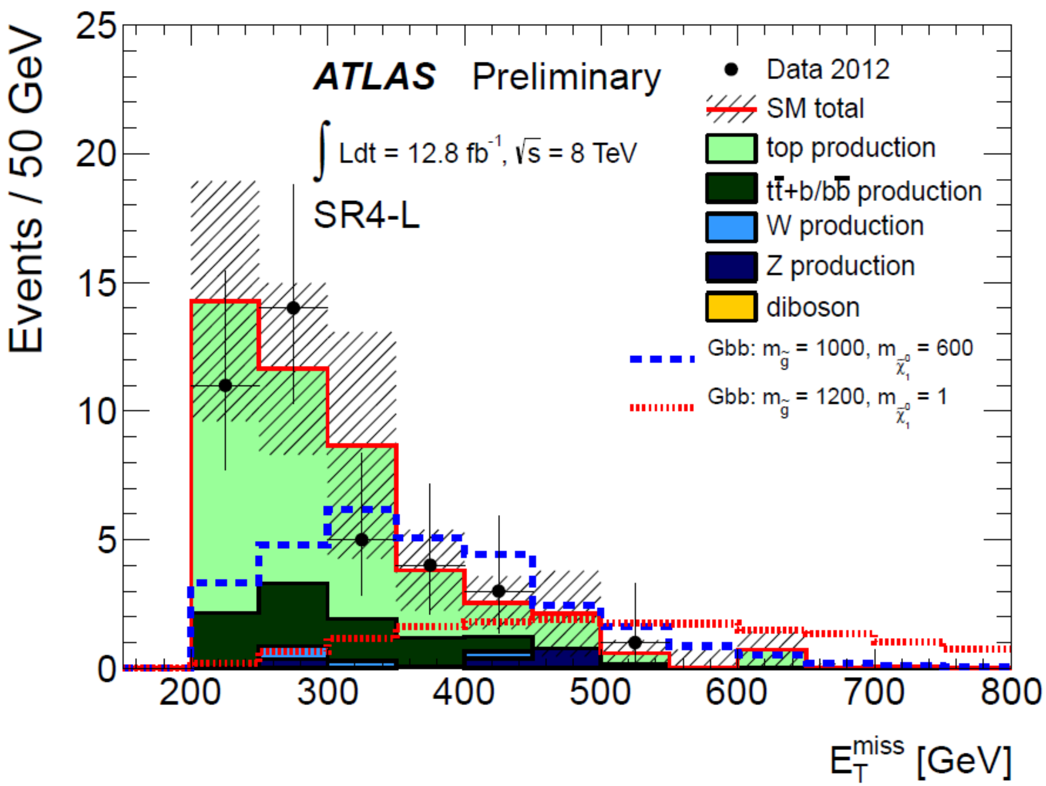
effective mass m_{eff} is scalar sum of MET and p_T of all (or selected number of) jets.

Search for SUSY particles

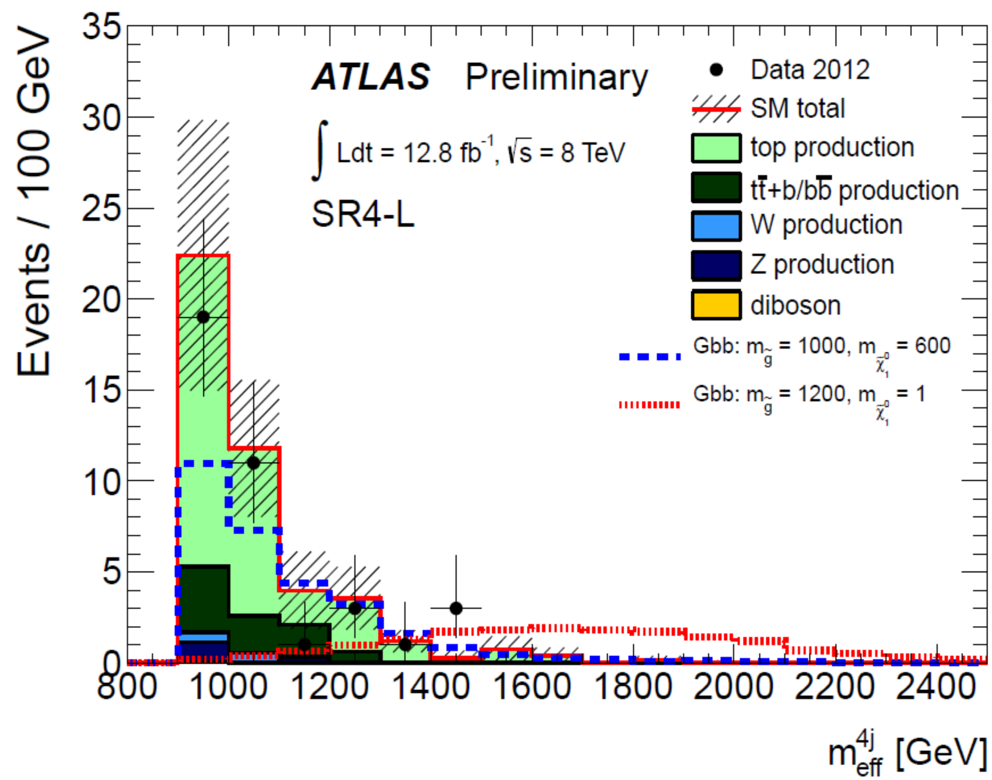
ATLAS-CONF-2012-145

ATLAS search for gluino pairs in final states with ≥ 3 b-jets and MET

Missing transverse energy:



4-jet effective mass:



- Dominant background: tops
- Background control validated on signal-free control regions.
- No excess observed, need more data to set limits on high mass LSPs

Search for SUSY particles

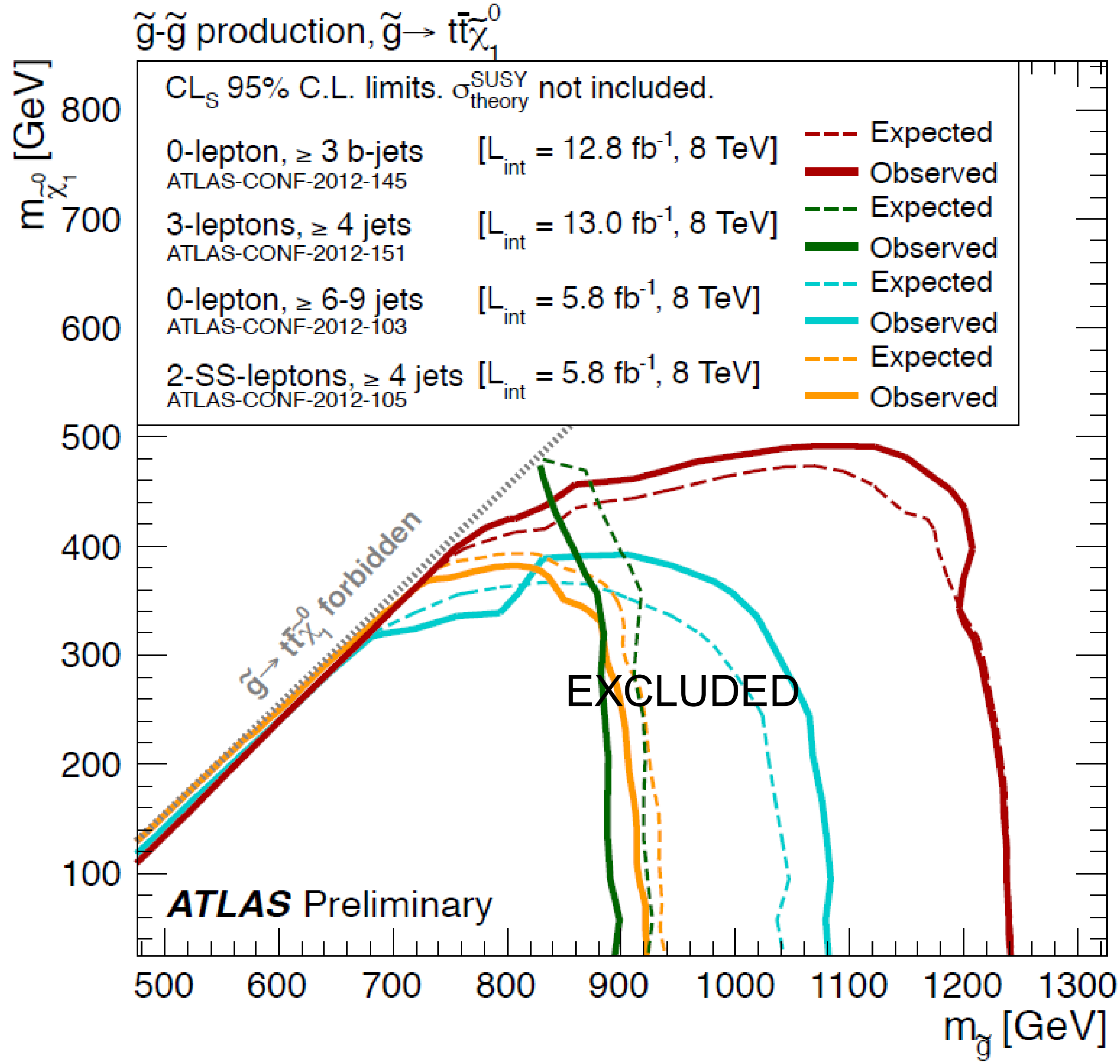
ATLAS search for gluino pairs: Summary of Results

Interpretation in a simplified model where $\tilde{t}_1$ is lightest squark but

$$m_{\tilde{g}} < m_{\tilde{t}_1}$$

and BR=100% for

$$\tilde{g} \rightarrow t\bar{t}\tilde{\chi}_1^0$$



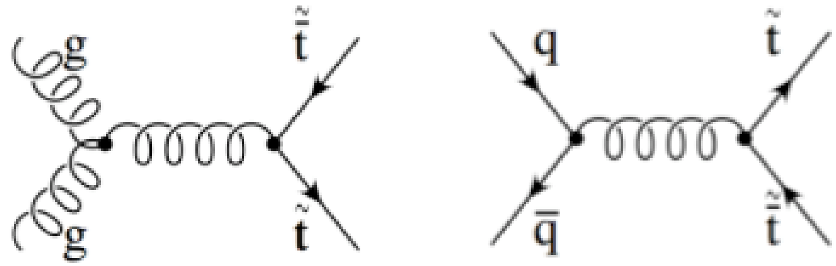
→ **No excess observed, but stringent limits set!**

Search for SUSY particles

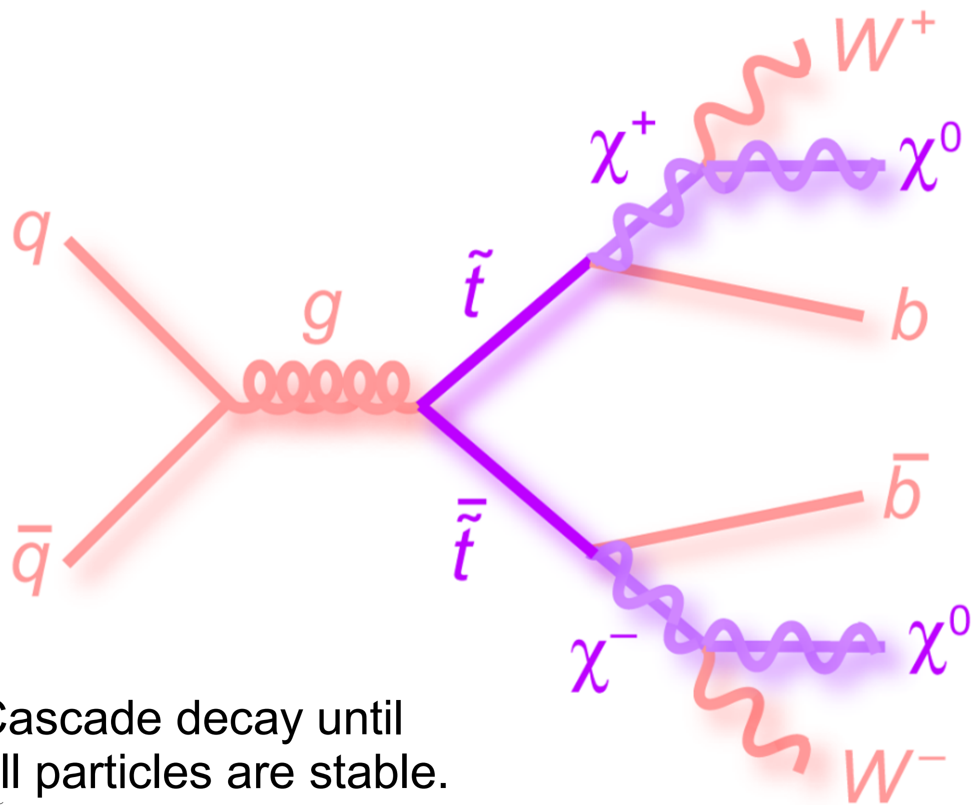
ATLAS-CONF-2012-166

ATLAS search for direct stop pairs in final states with one lepton, jets and MET

Stop pair production:



Stop pair decay:



1. $$\tilde{t}_1 \rightarrow b + \tilde{\chi}_1^{\pm}$$ with $\tilde{\chi}_1^{\pm} \rightarrow W^{(*)} + \tilde{\chi}_1^0$

2. $$\tilde{t}_1 \rightarrow t + \tilde{\chi}_1^0$$ with $t \rightarrow bW$

Cascade decay until all particles are stable. $\tilde{\chi}^0_1$ is long-lived (it leaves detector).

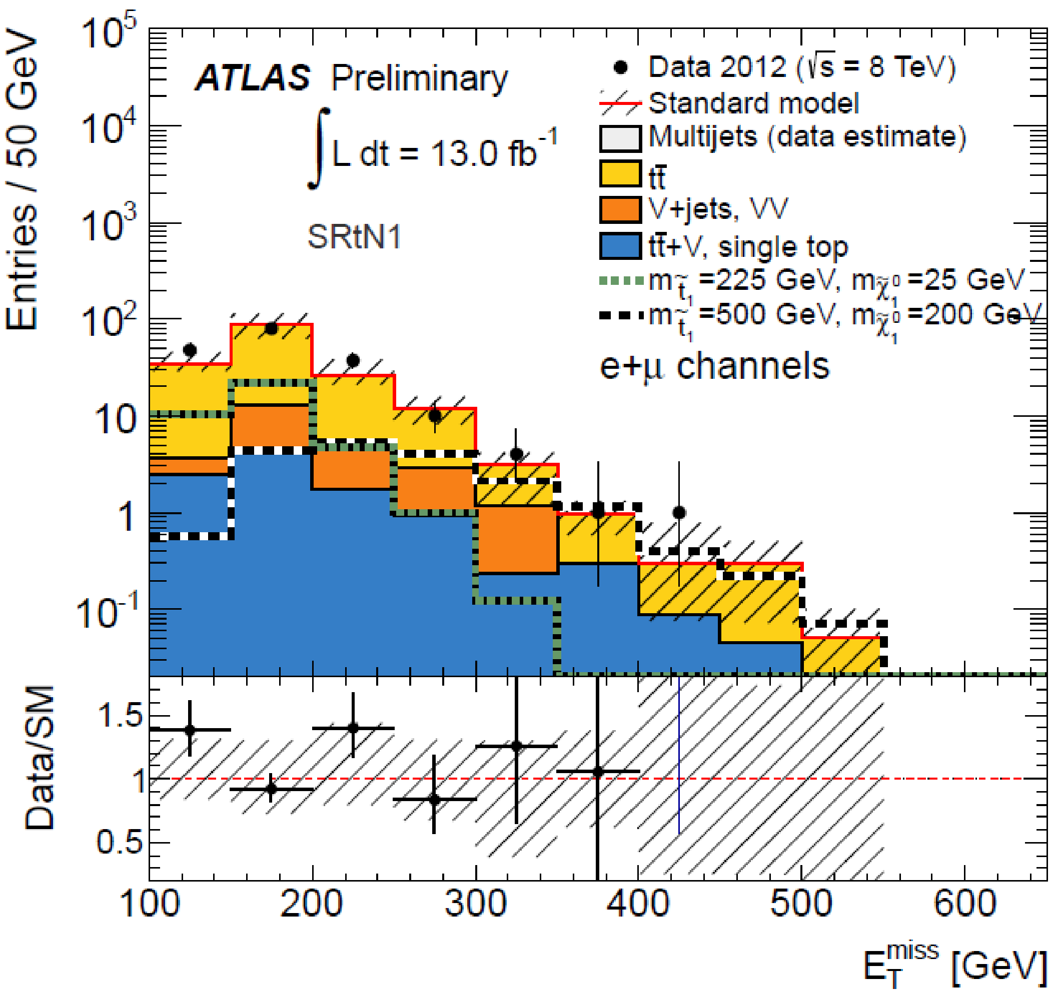
Both decays have similar final states (W's, b-jets, leptons, MET) but different kinematics

Search for SUSY particles

ATLAS-CONF-2012-166

ATLAS search for direct stop pairs in final states with one lepton, jets and MET

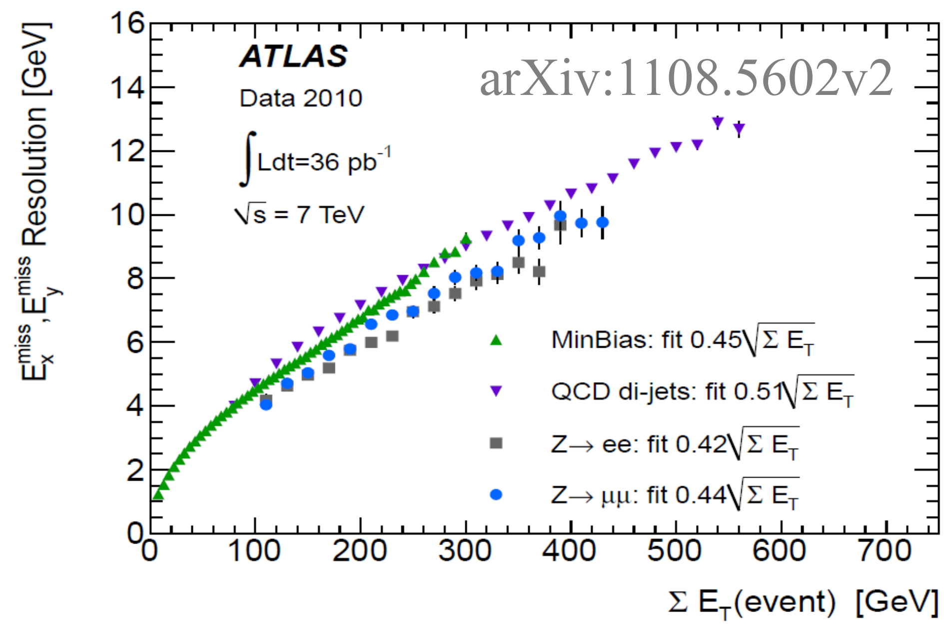
Neutralinos escape direct detection → they manifest as missing energy
The heavier the stops and neutralinos, the more MET can be expected:



Dominant bkg: top pairs

MET is not a precise variable:

The MET resolution deteriorates with the total pT of the objects:

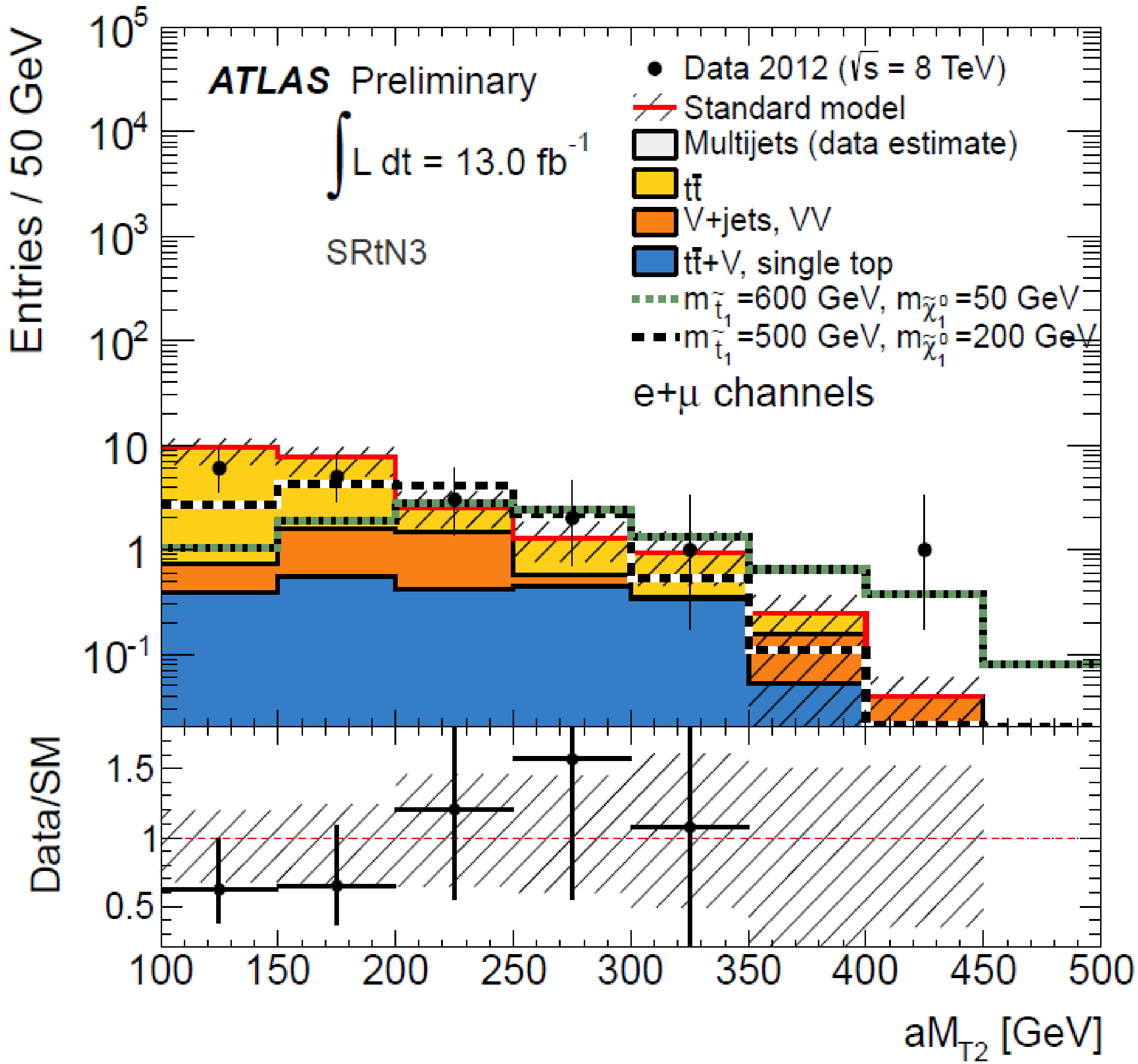


MET also depends on the pile-up.

Search for SUSY particles

ATLAS-CONF-2012-166

ATLAS search for direct stop pairs in final states with one lepton, jets and MET



Better than MET would be to reconstruct the stop mass, but this is very difficult when dealing with cascade decays and two massive neutral particles in the final state.

Variable used: am_{T2}.

Useful to supress top background!

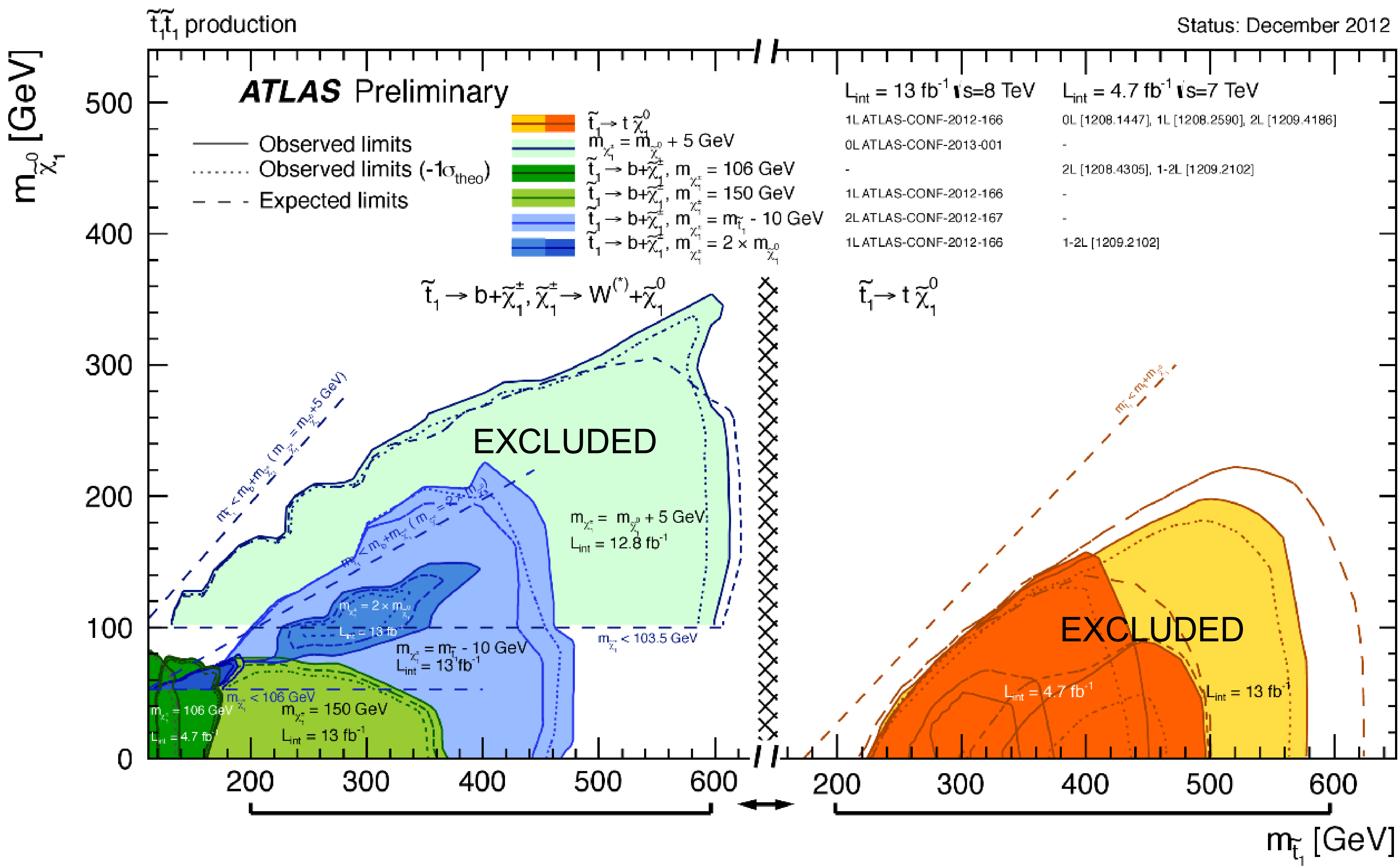
This is a generalized transverse mass inspired from W mass meaurement:

arXiv:hep-ph/9906349v1

SUSY signal extends to larger values of aM_{T2} than the top background.

Search for SUSY particles

ATLAS search for stop pairs: Summary of Results



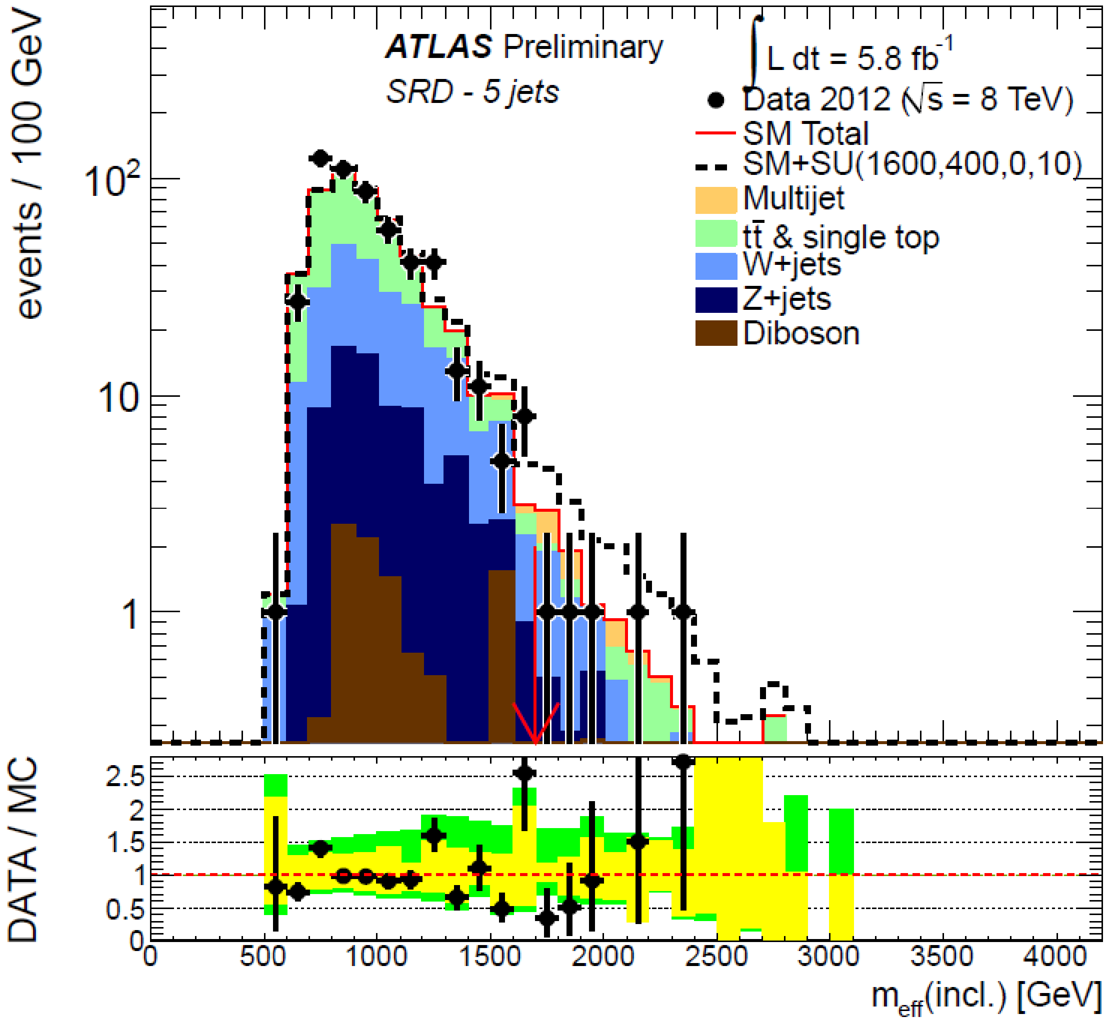
→ **No excess observed, but stringent limits set!**

Search for SUSY particles

ATLAS generic search for squarks and gluinos in final states with MET and jets

Interprete in constrained MSSM model with assumptions on SUSY breaking parameters

Example signal region with MET > 160 GeV and 5 jets:



arXiv:1109.3859v3

„Constrained MSSM' (cMSSM):

Reduce ~100 SUSY parameters to a few

→ Specific model: **mSUGRA**

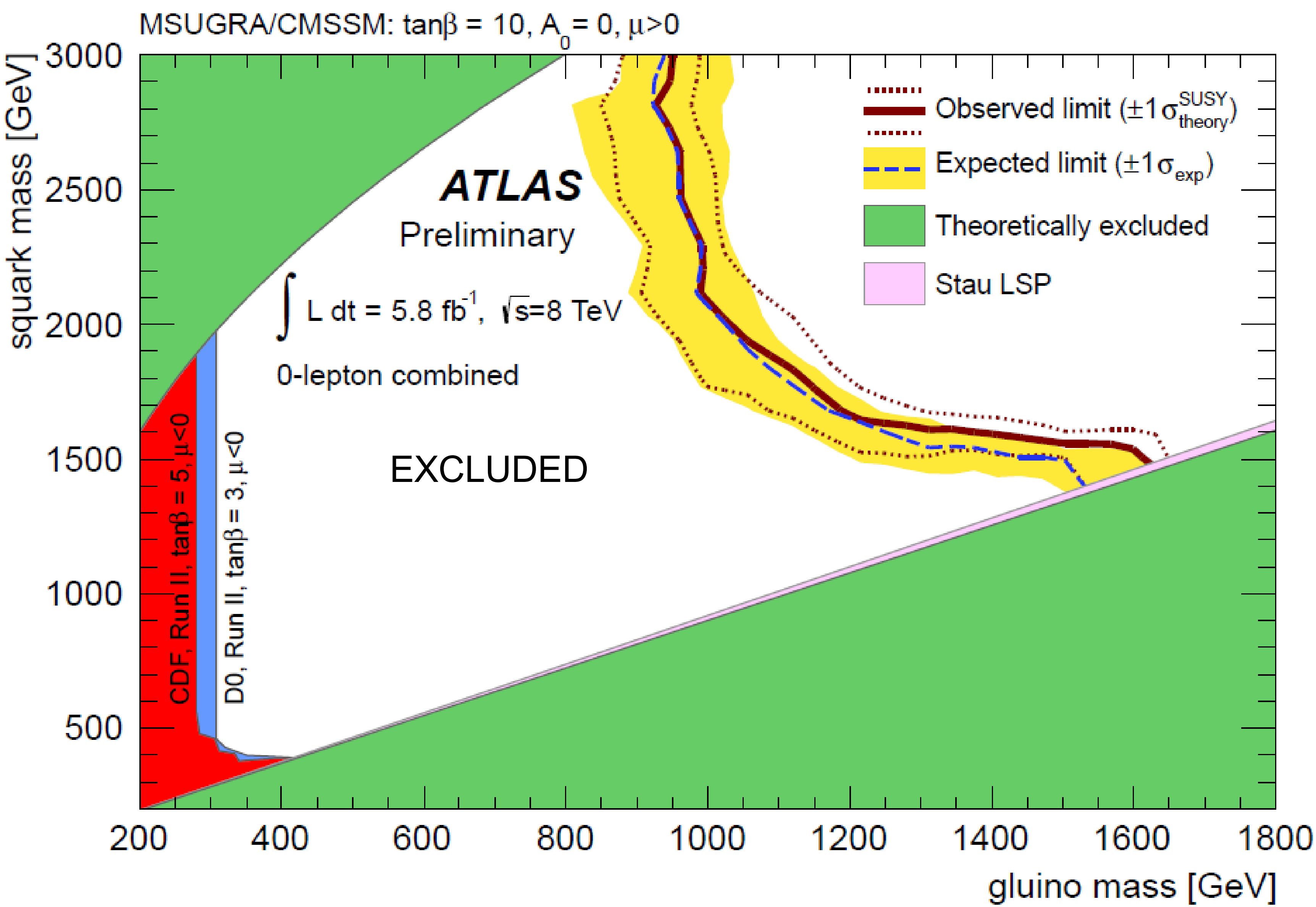
mSUGRA is minimal Supergravity model where gravity breaks SUSY. Gaugino masses, sfermion masses, scalar masses unify at GUT scale.

Parameters:

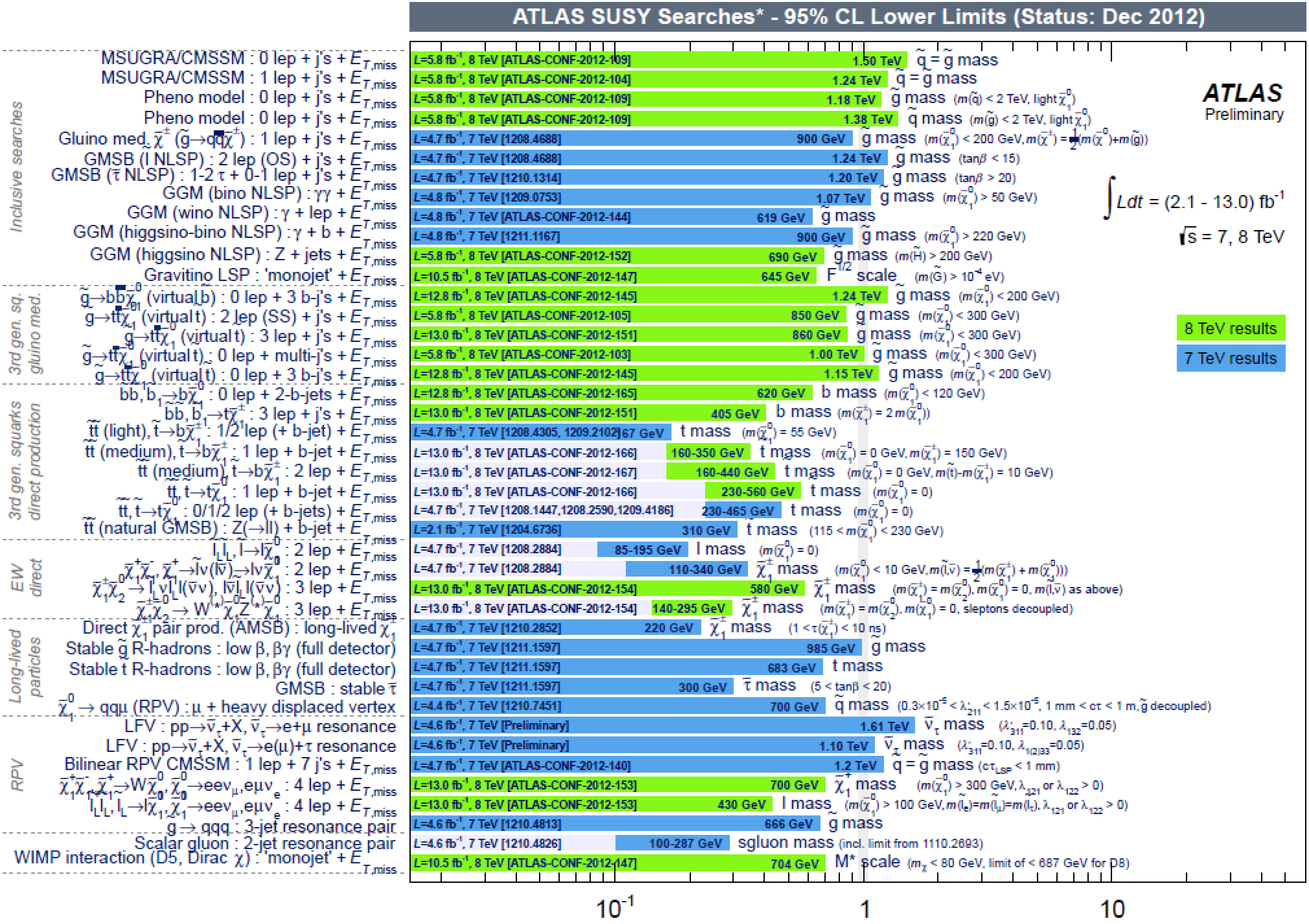
- M_0 scalar mass
- $M_{1/2}$ gaugino mass
- A_0 trilinear coupling
- $\tan\beta$
- μ Higgsino mass parameter

Search for SUSY particles

ATLAS generic search for squarks and gluinos in final states with MET and jets



→ **No excess observed, but stringent limits set!**



*Only a selection of the available mass limits on new states or phenomena shown.
All limits quoted are observed minus 1σ theoretical signal cross section uncertainty.

Exotics

(selection)

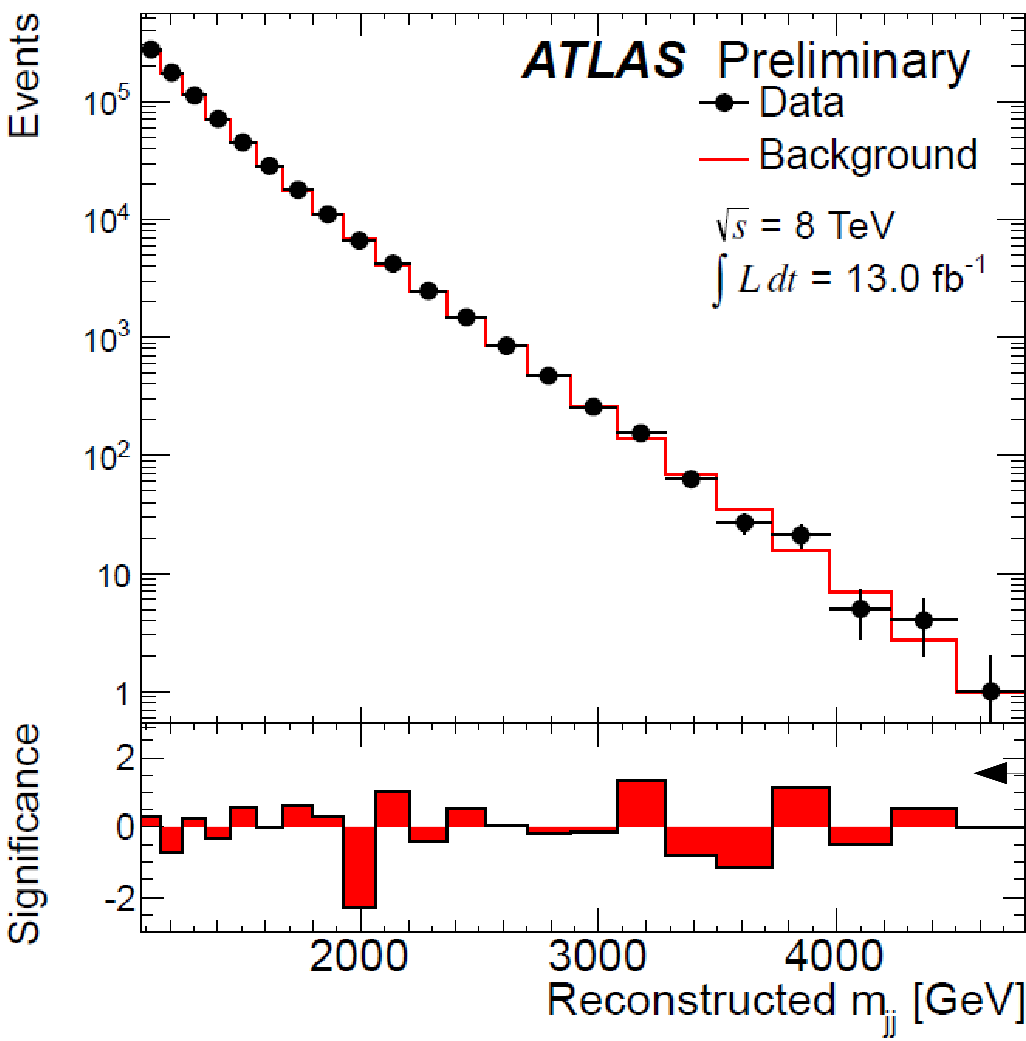
Search for New Phenomena in the Dijet Mass

ATLAS-CONF-2012-148

Testing the SM up to the highest energies at LHC.

Aim: Look for **excited quarks q* → qg** (ie. quark sub-structure) by probing dijet mass.

The SM dijet mass comes from non-resonant QCD dijet production.



Search strategy:

Look for bumbs in the dijet mass!

Background estimated from a fit to the dijet mass:

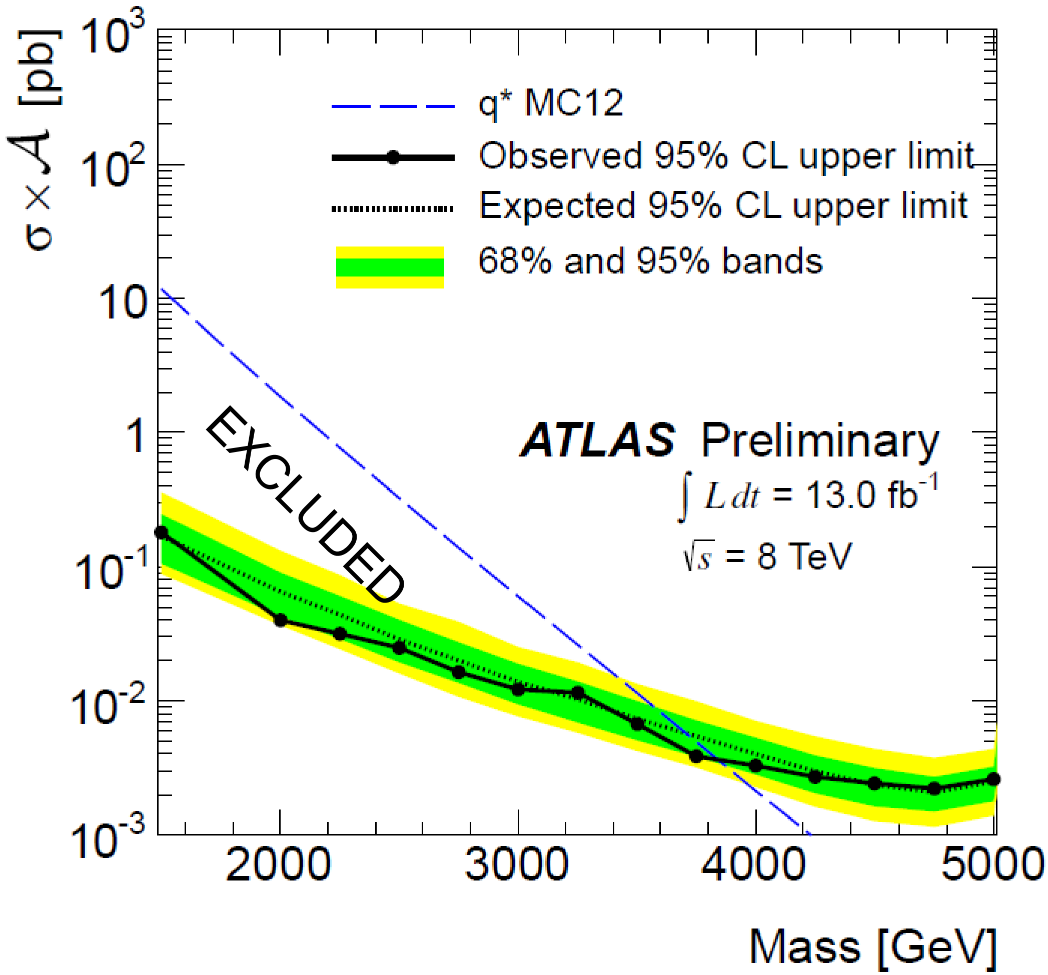
$$f(x) = p_1(1-x)^{p_2} x^{p_3+p_4 \ln x}$$

Significance does not contain systematic uncertainties.

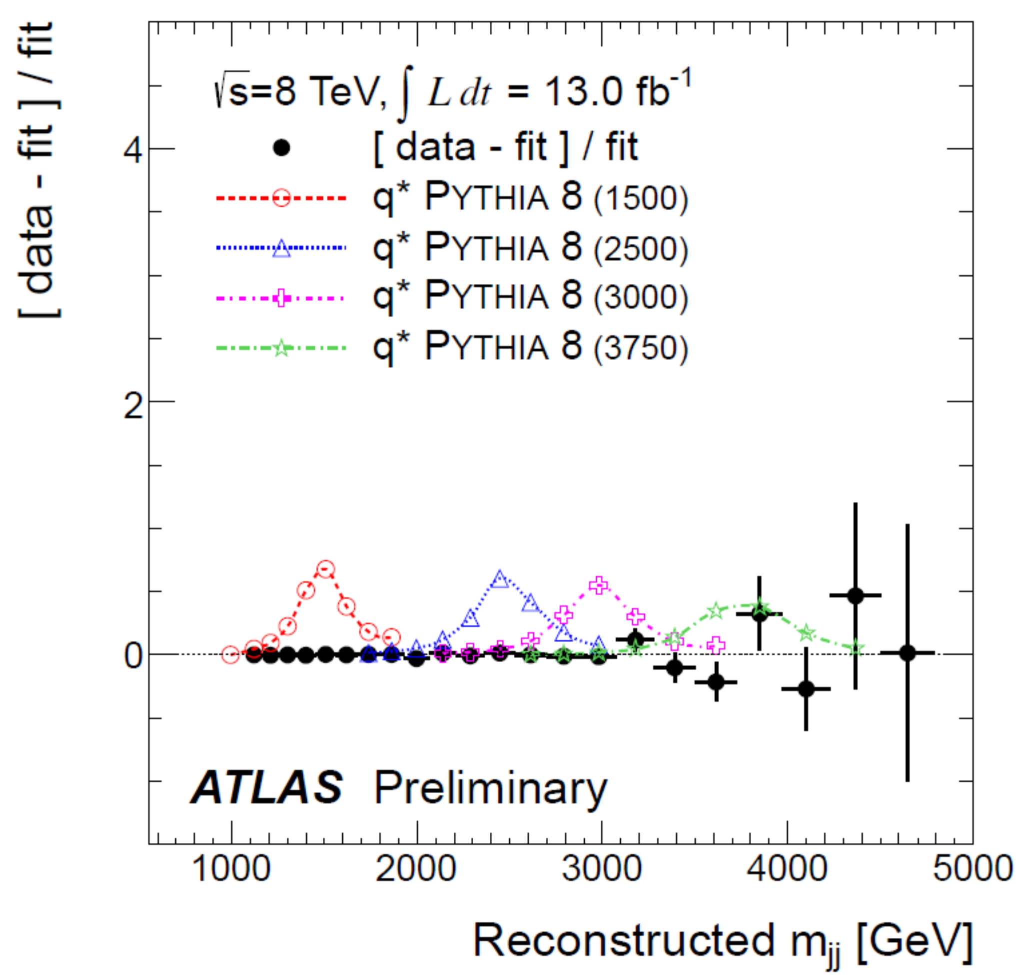
BumpHunter algorithm (arXiv:1101.0390)

Search for New Phenomena in the Dijet Mass

Cross section limits on excited quarks:

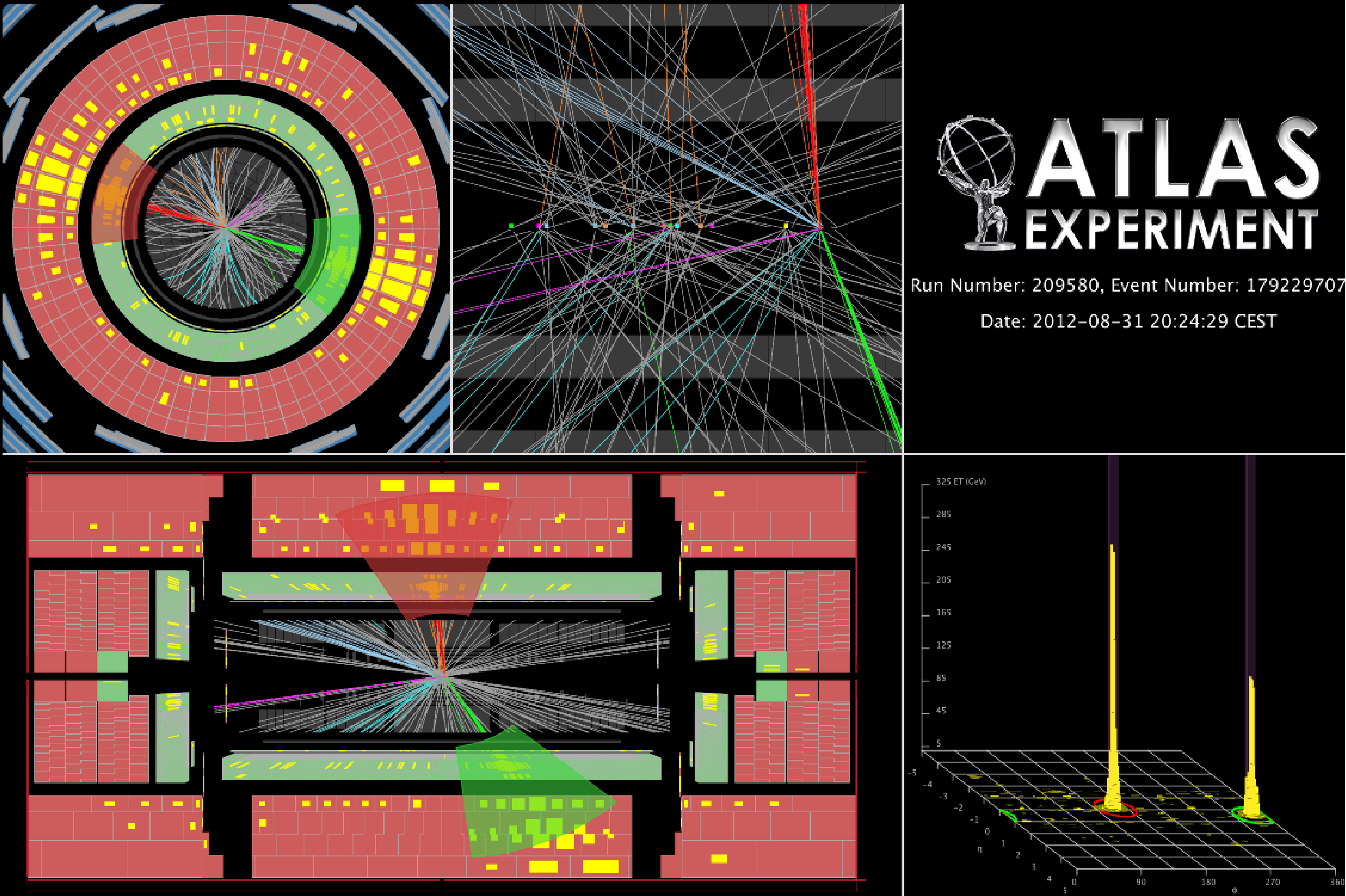


Bkg subtracted data vs. prediction:



→ **m_{q^*} > 3.84 TeV**

Highest dijet mass event: m_{jj} = 4.69 TeV. MET = 47 GeV.



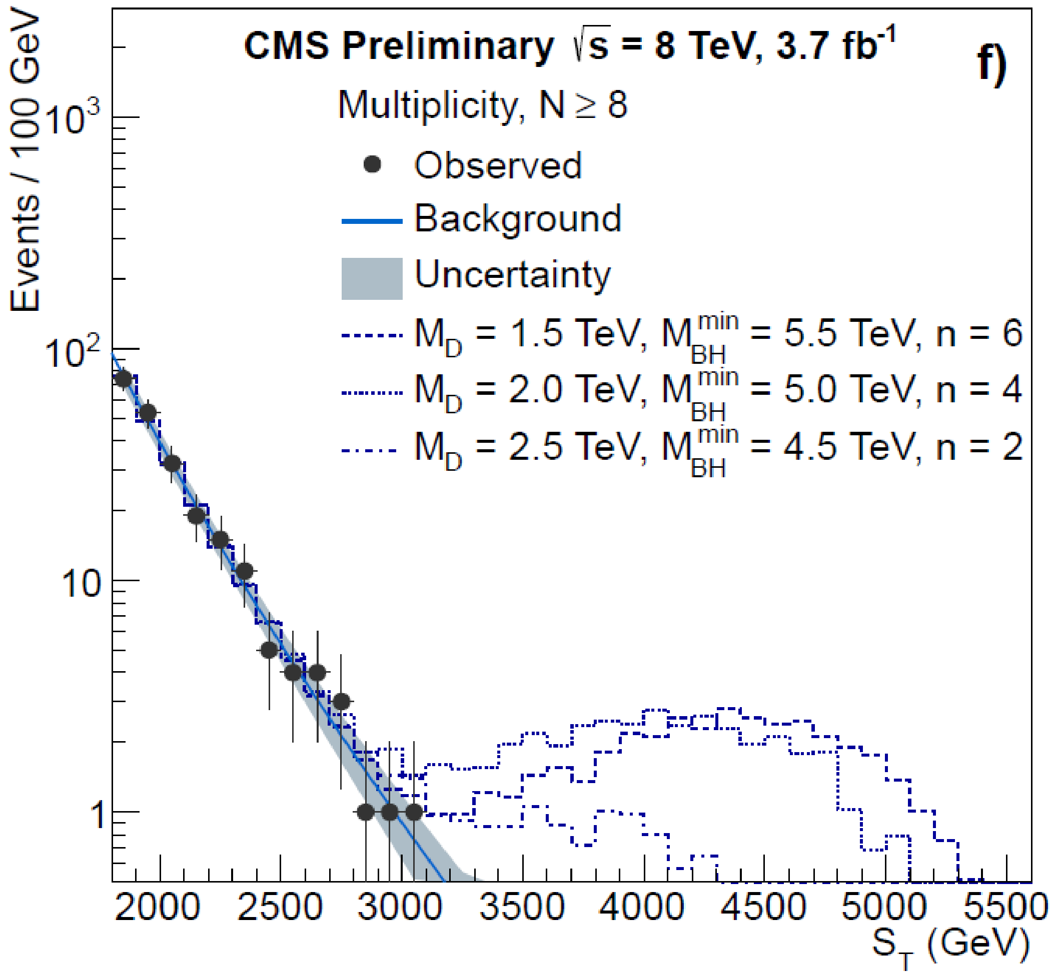
Search for Microscopic Black Holes

CMS-PAS-EXO-12-009

ADD (Arkani-Hamed, Dimopoulos, Dvali) model: n large, flat extradimensions.

New physics mass scale $$M_D^{n+2} \propto M_{\rm Pl}^2 R^{-n}$$

With M_{pl} Planck scale (10^{19} GeV), and R size of the extra dimensions



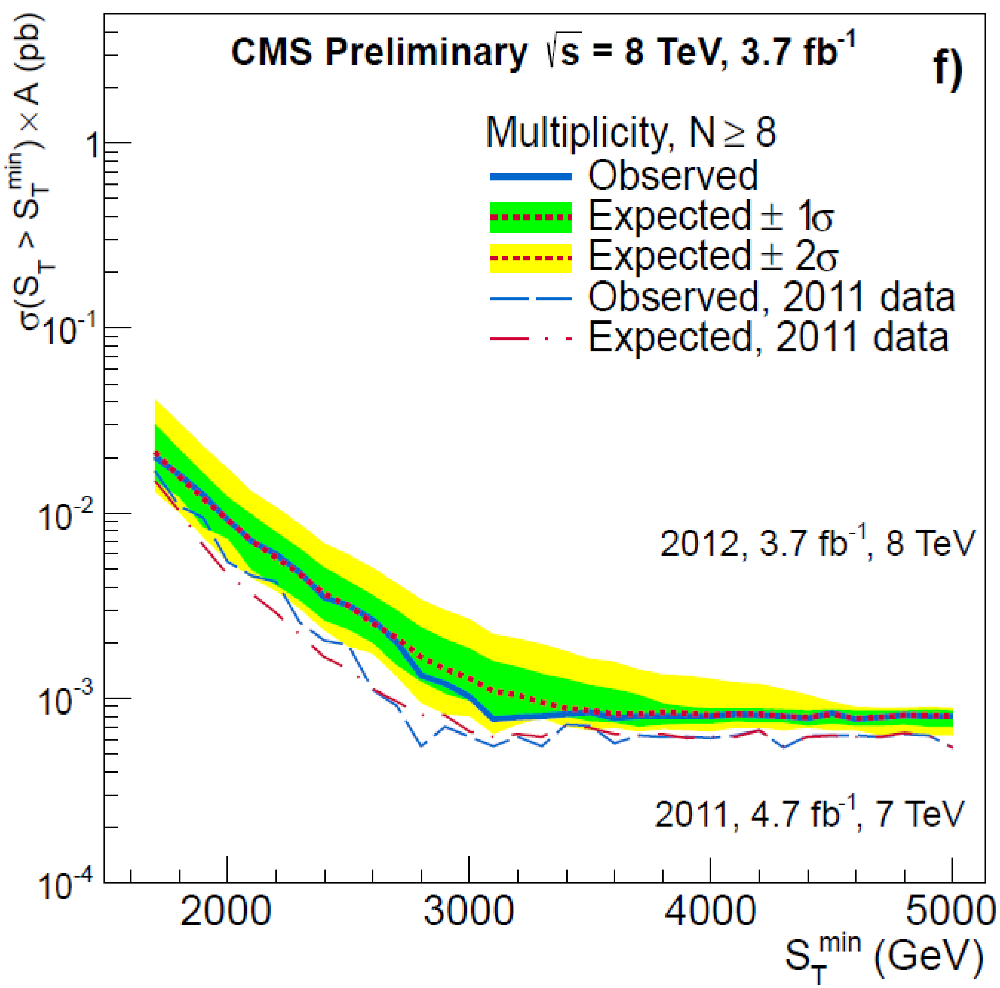
Search strategy:

The black hole evaporates and a large amount of particles are produced
→ look for large MET, events with high jet mulitplicty, large scalar sum of E_T (S_T variable)

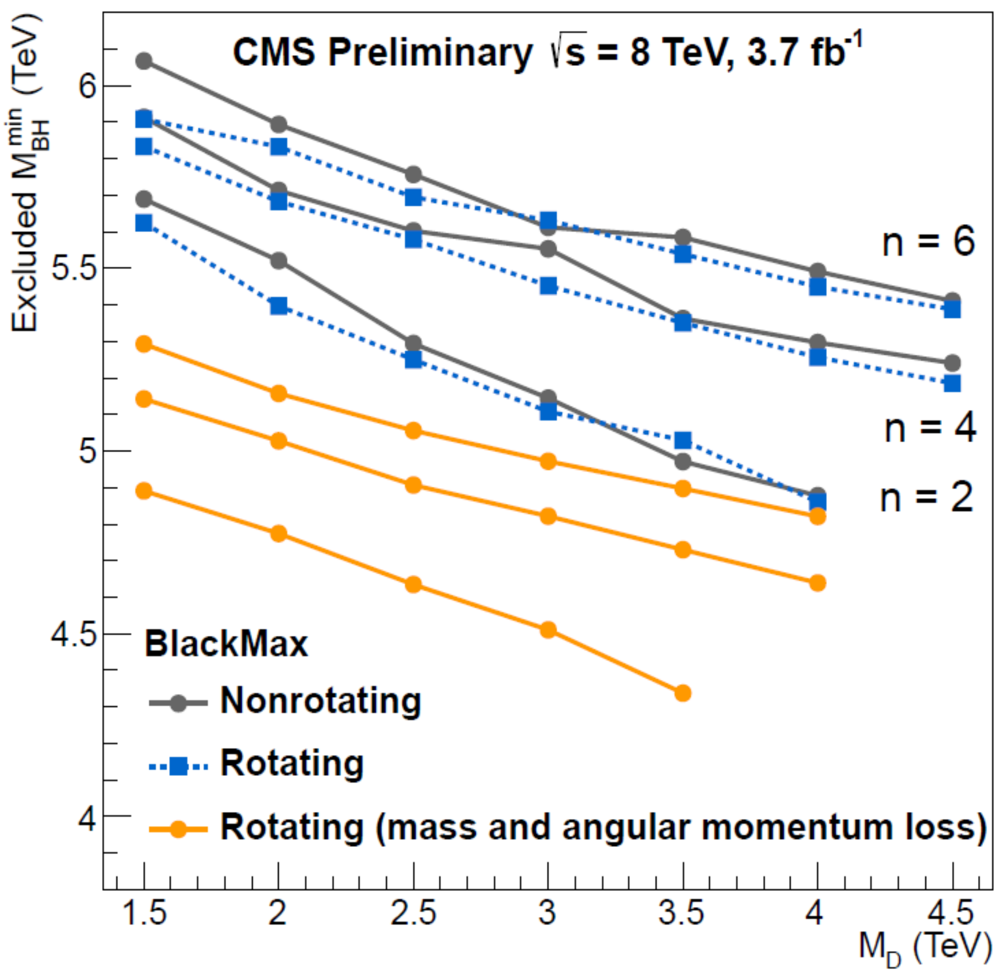
Main background: QCD multi-jet events

Search for Microscopic Black Holes

Model independent limit:

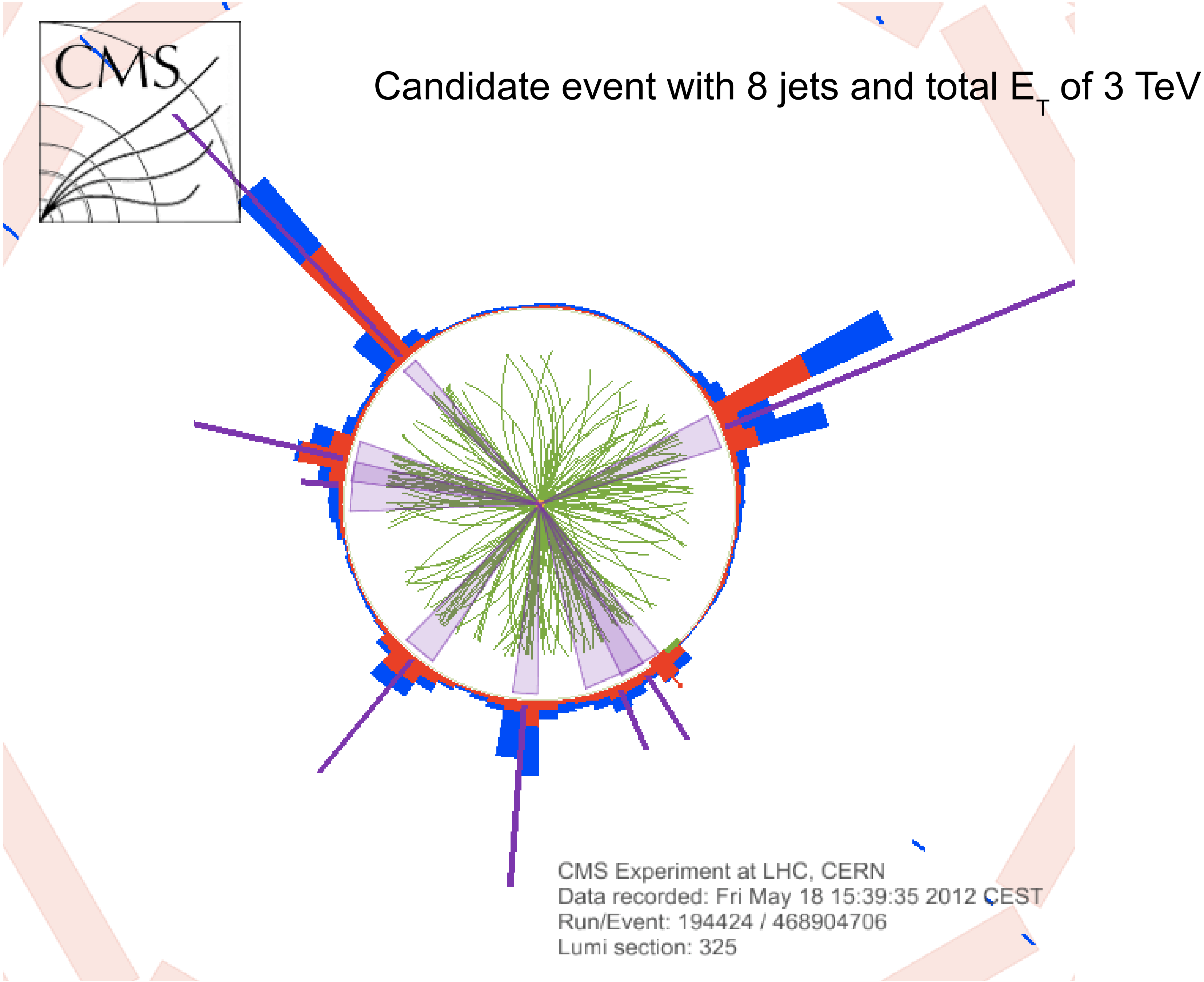


Limits on BH masses for specific models:



→ **No excess observed!**

Search for Microscopic Black Holes



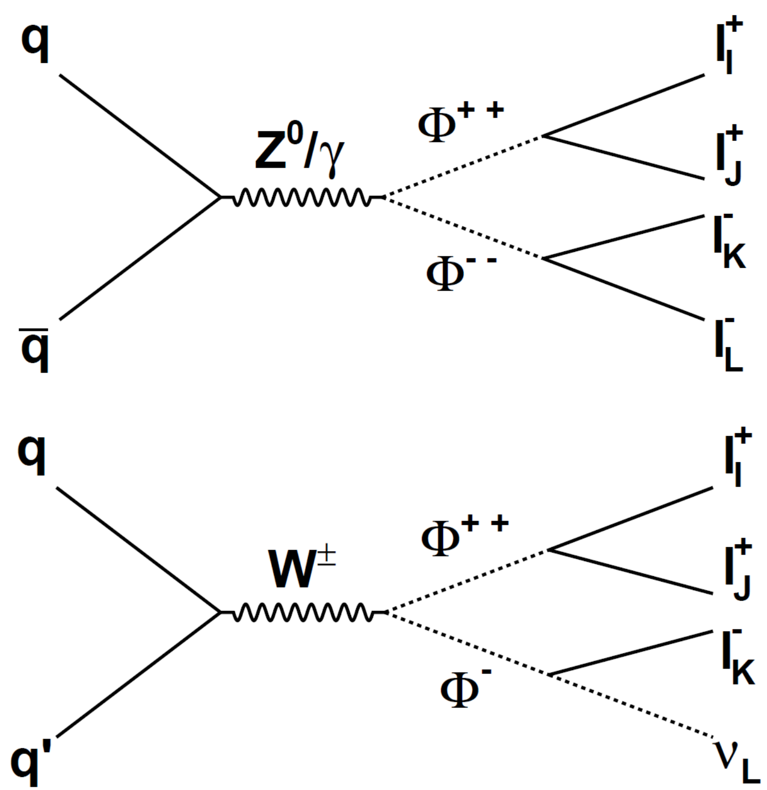
Exotic Higgs Searches: Doubly-charged Higgs

CMS Search for $\Phi^{\pm\pm} \rightarrow 2l$

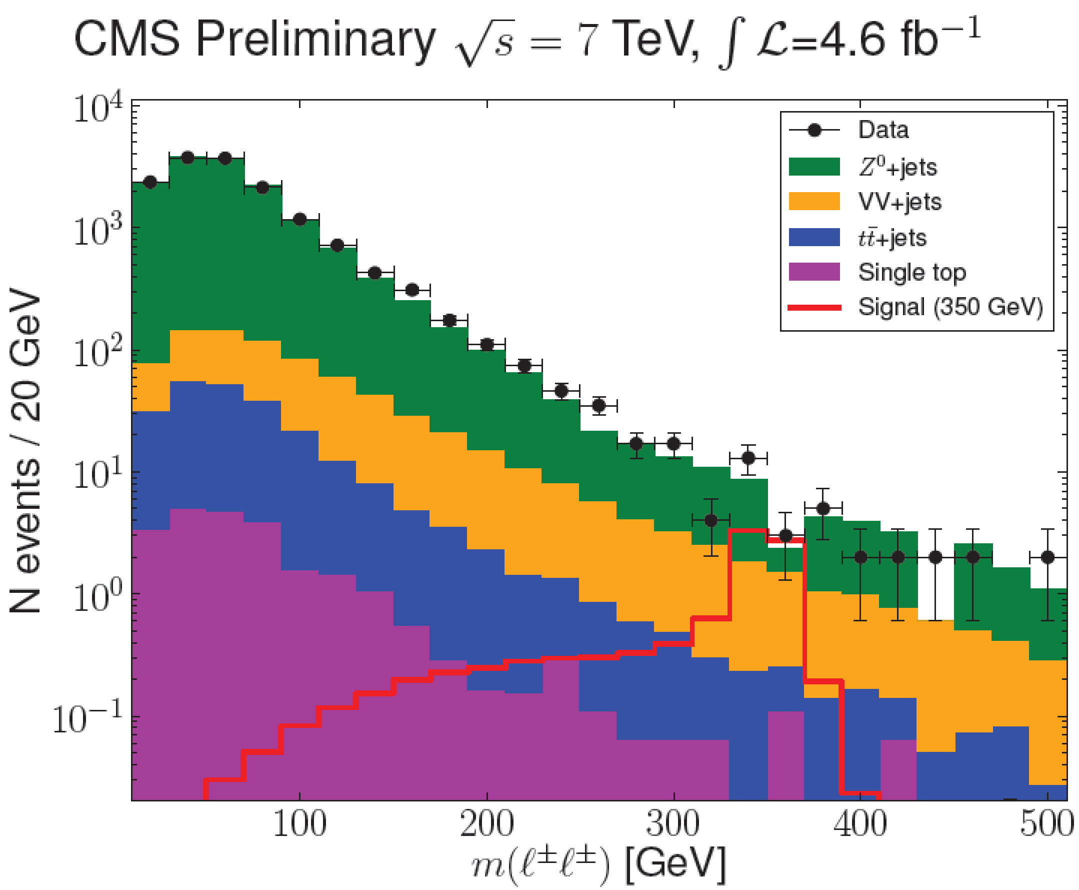
CMS PAS HIG-12-005

In the SM : One Higgs doublet
In the MSSM: Two Higgs doublets
In the NMSSM: Two Higgs doublets + one singlet
...
Even more exotic: One Higgs triplet

Production/decay of doubly-charged Higgs:

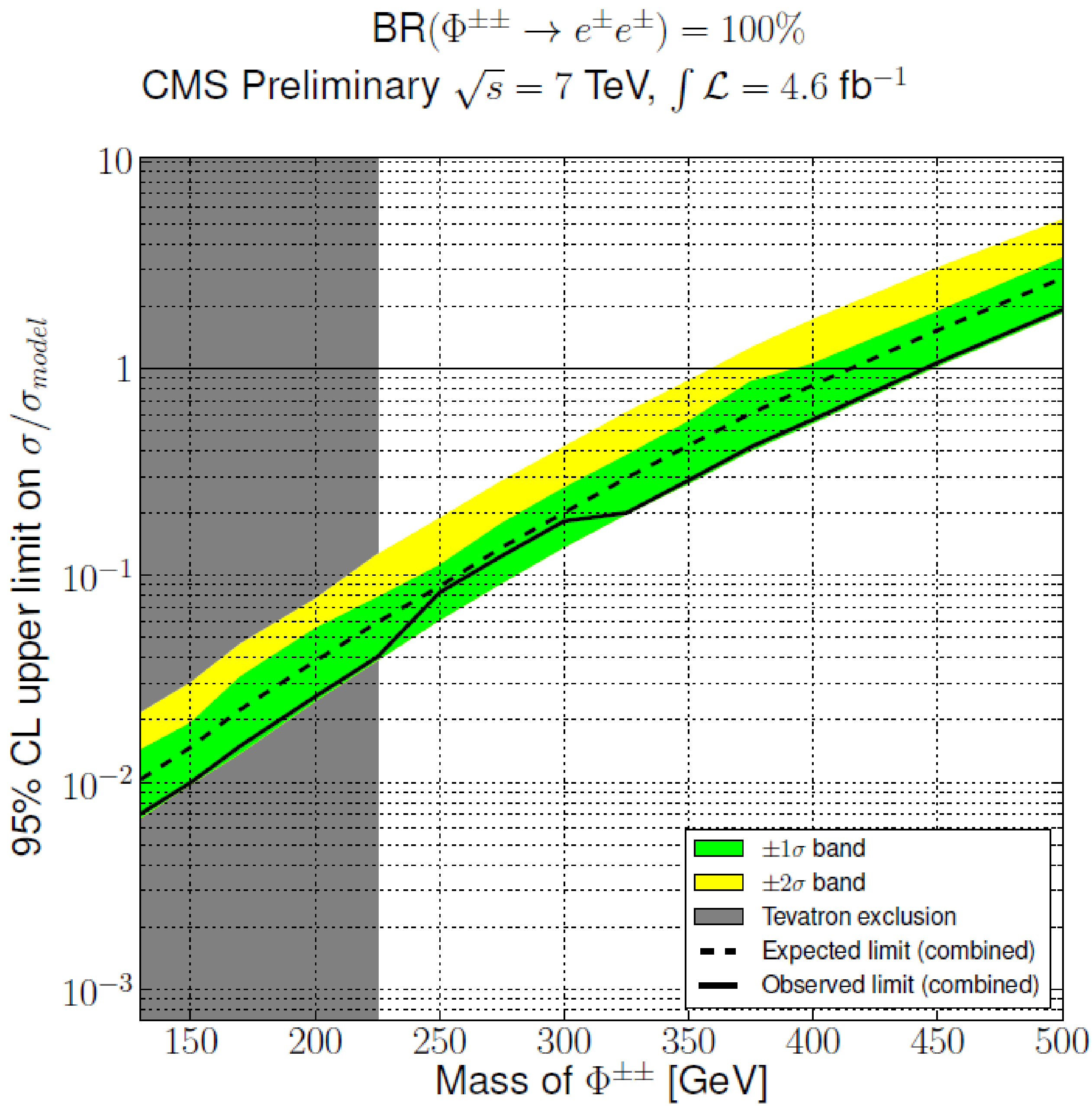


Dilepton mass spectrum:



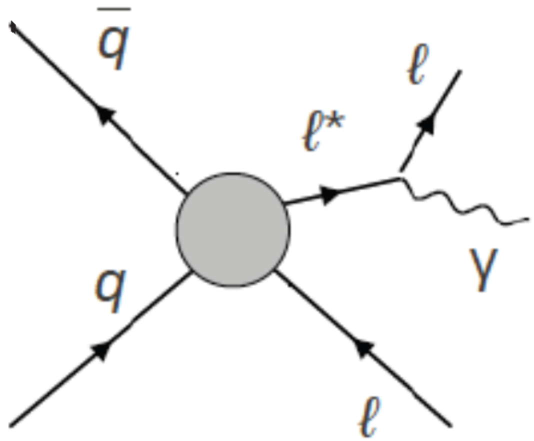
→ look for same charge leptons!

Exotic Higgs Searches: Doubly-charged Higgs



→ **No excess observed!**

Search for excited electrons and muons



Is the lepton a composite particle?

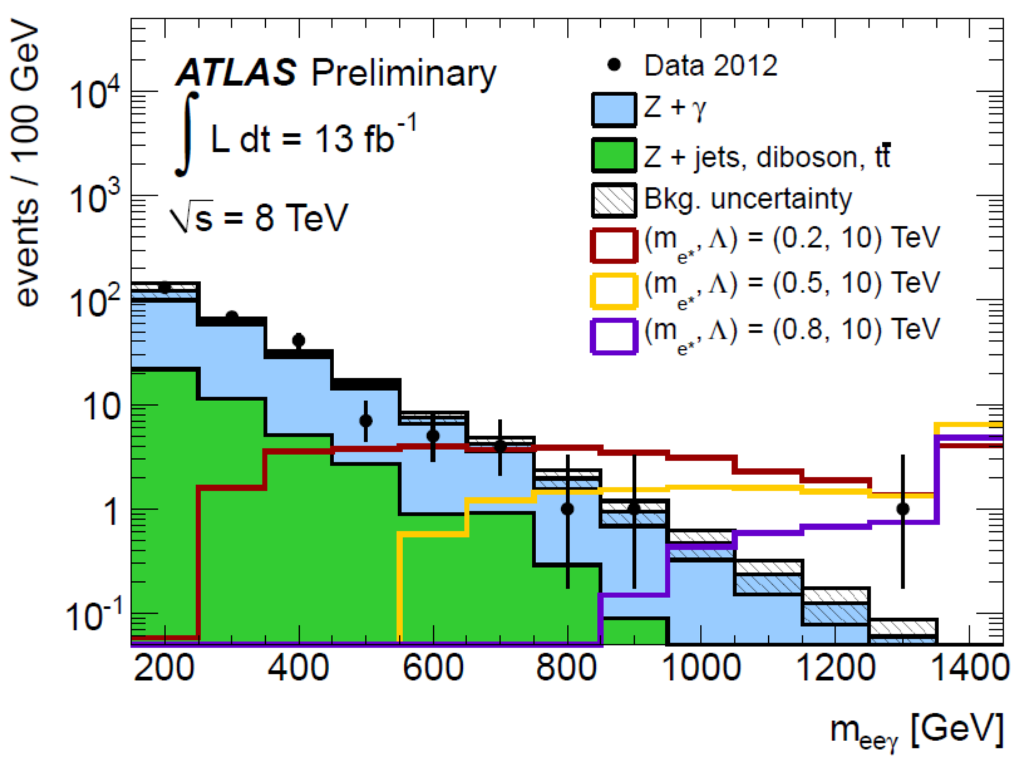
← Event signature: two leptons and a photon

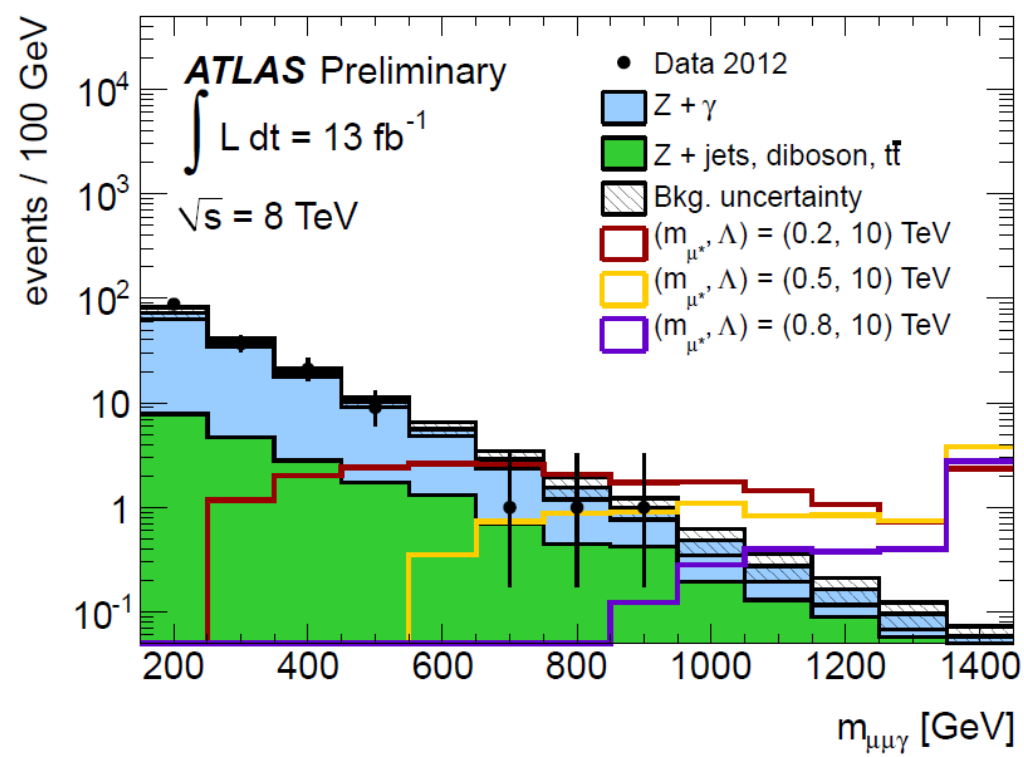
Look for $\mathbf{q\bar{q} \rightarrow ll^* \rightarrow ll\gamma}$ in $ee\gamma$ and $\mu\mu\gamma$ final states

Since no signs of compositenseses found previously, compositness scale Λ must be large.

$p_T(\gamma) > 30$ GeV

ATLAS-CONF-2012-146

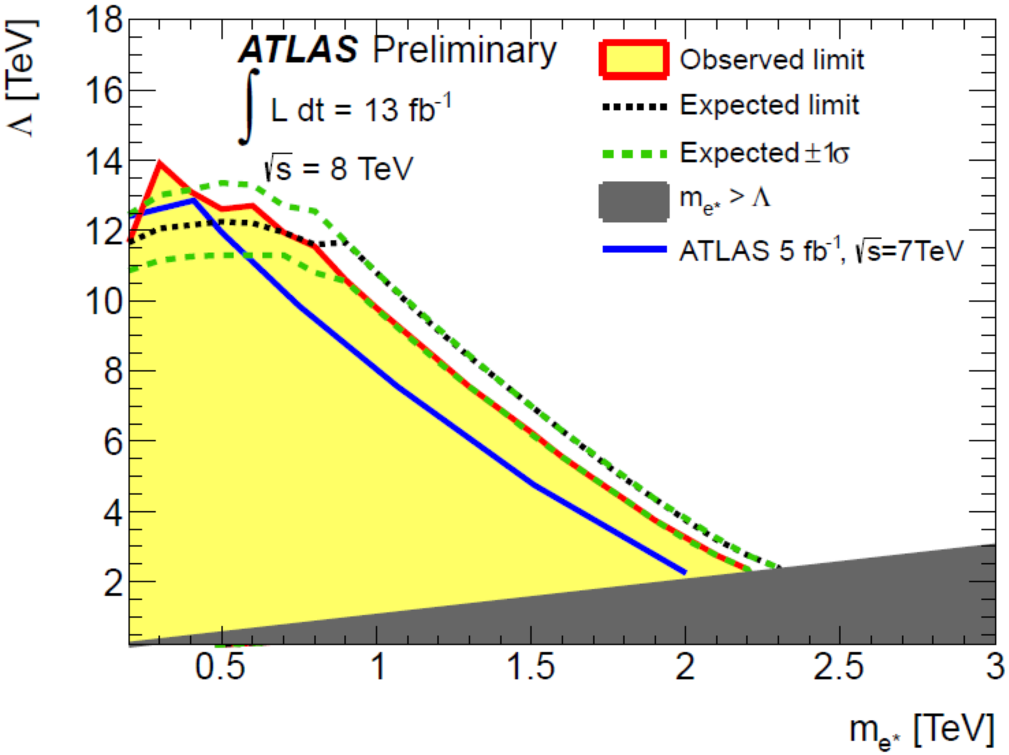




Search for excited electrons and muons

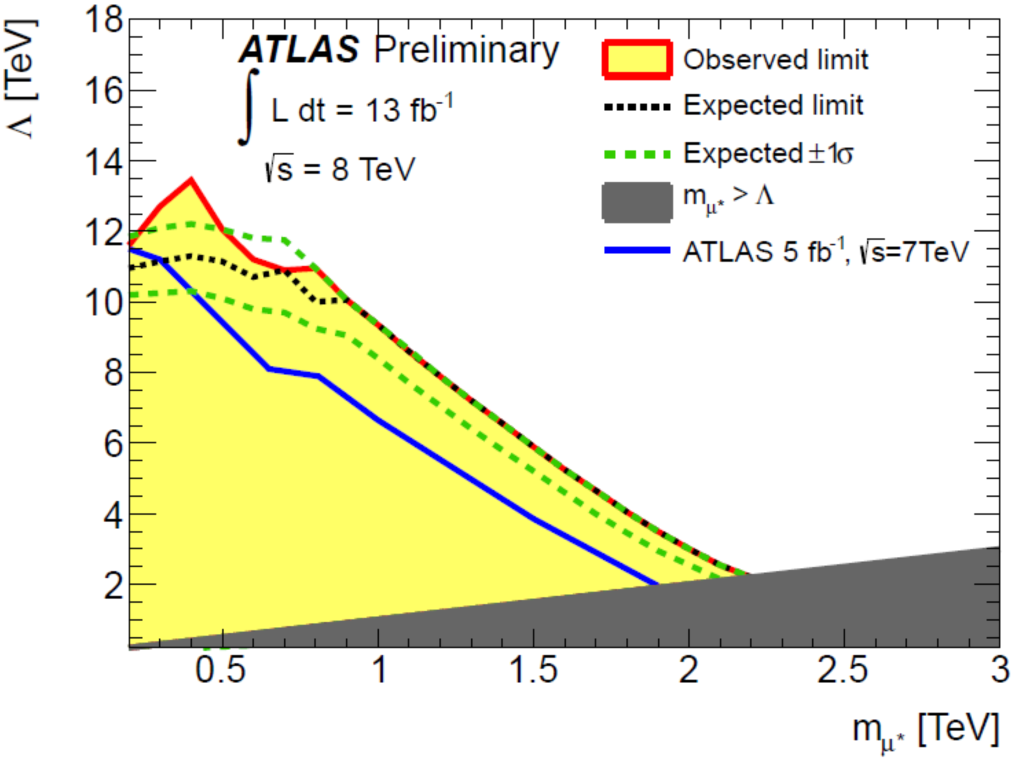
Limits are set on the excited electron and exctited muon mass as a function of the compositeness scale Λ.

Excited electron:



$m_{e^*} > 2.2$ TeV for $\Lambda = m_{e^*}$

Excited muon:

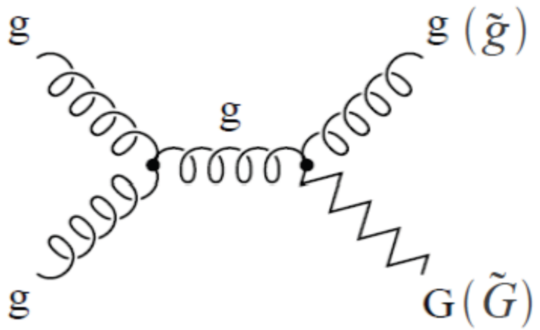


$m_{\mu^*} > 2.2$ TeV for $\Lambda = m_{\mu^*}$

→ **No excess observed!**

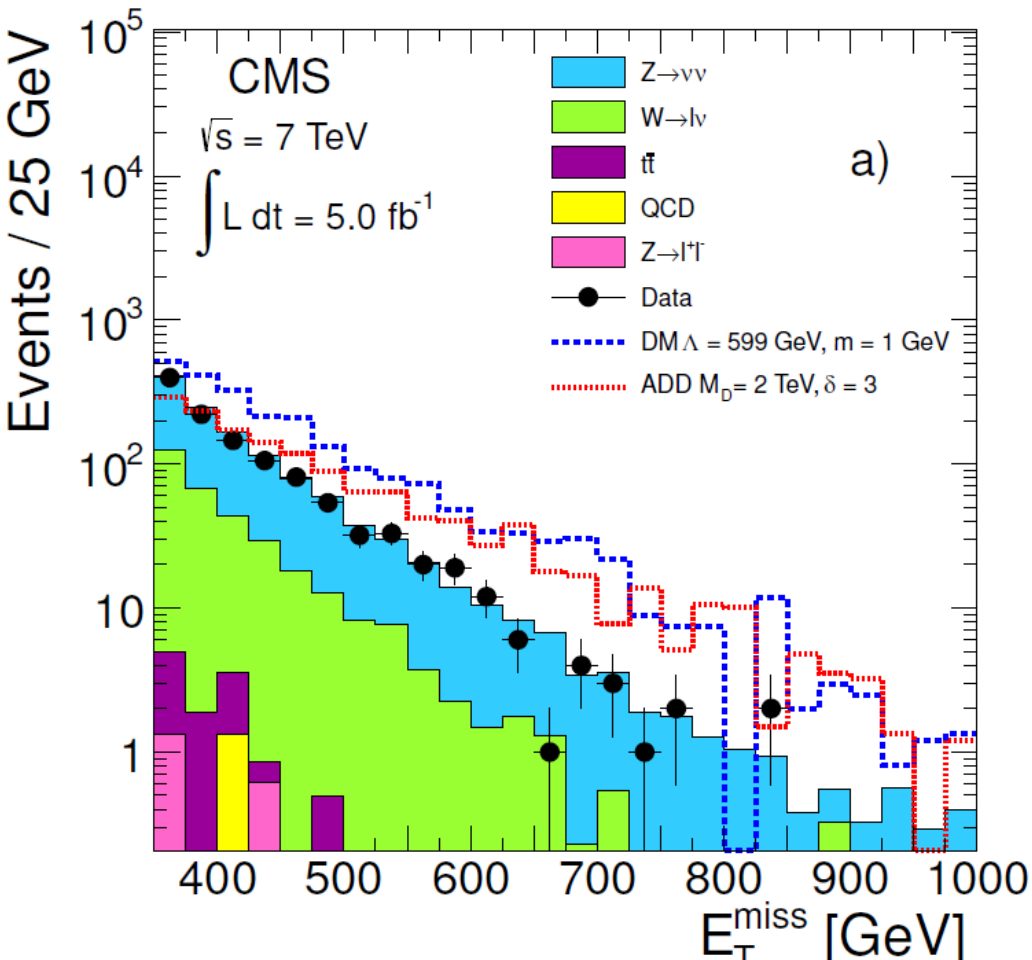
Search for dark matter and extra dimenions with monojets

Graviton + mono-jet production:

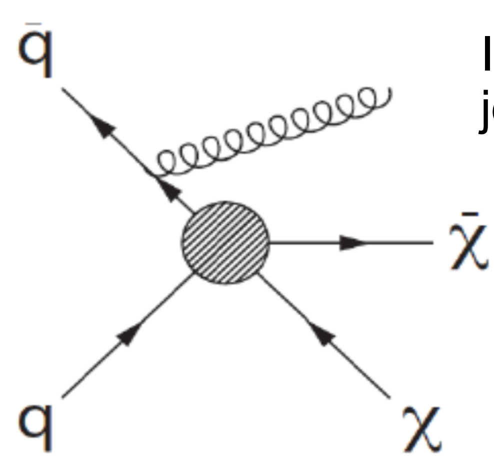


Graviton is precited in models with large extra dimensions (ADD models).

Graviton cross section is then large, it is not confined to the 4D brane where the SM lives.



Wimp-pair production:



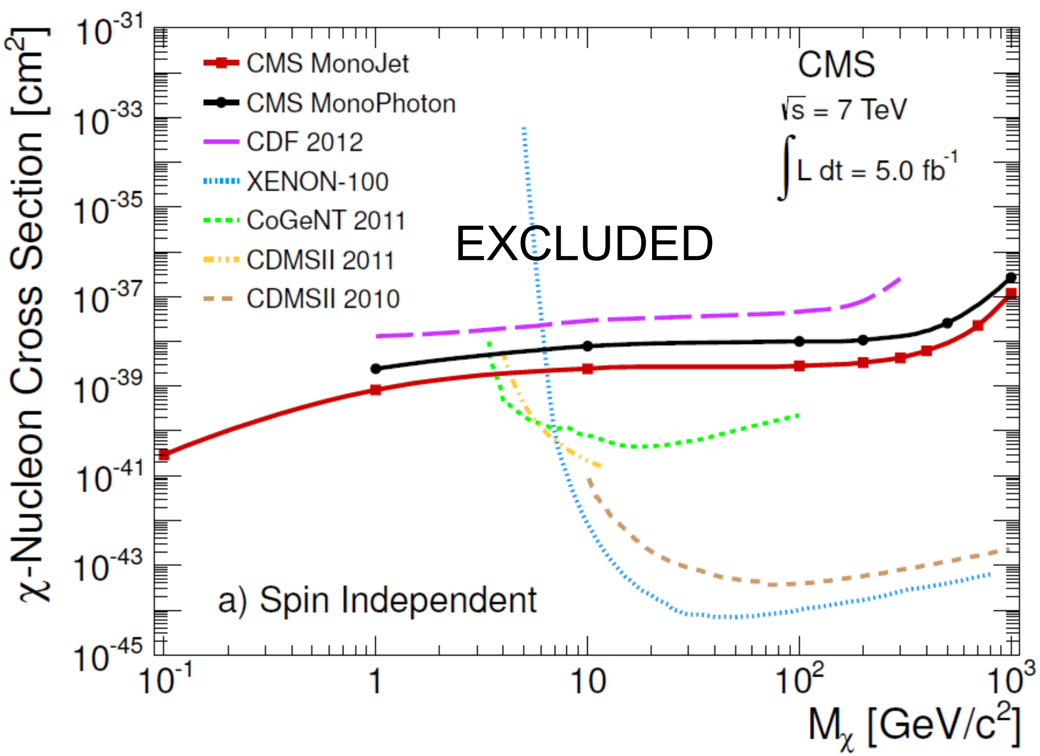
Wimp: Massive, interacting massive particle
→ Dark matter candidate.

Wimps and gravitons do not interact with the detector, but leave MET.

Search for dark matter and extradimenions with monojets

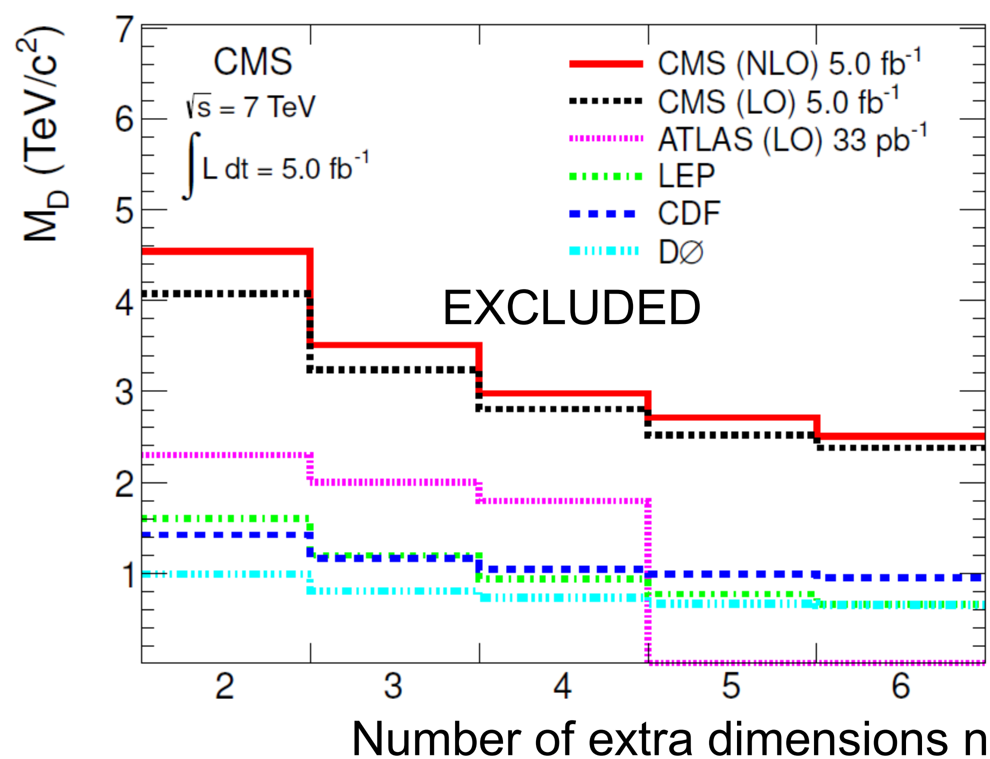
arXiv:1206.5663v1

Limits on wimp-nucleon scattering cross section:



Better limits than direct searches for m_χ < 3 GeV.

ADD mass scale parameter:

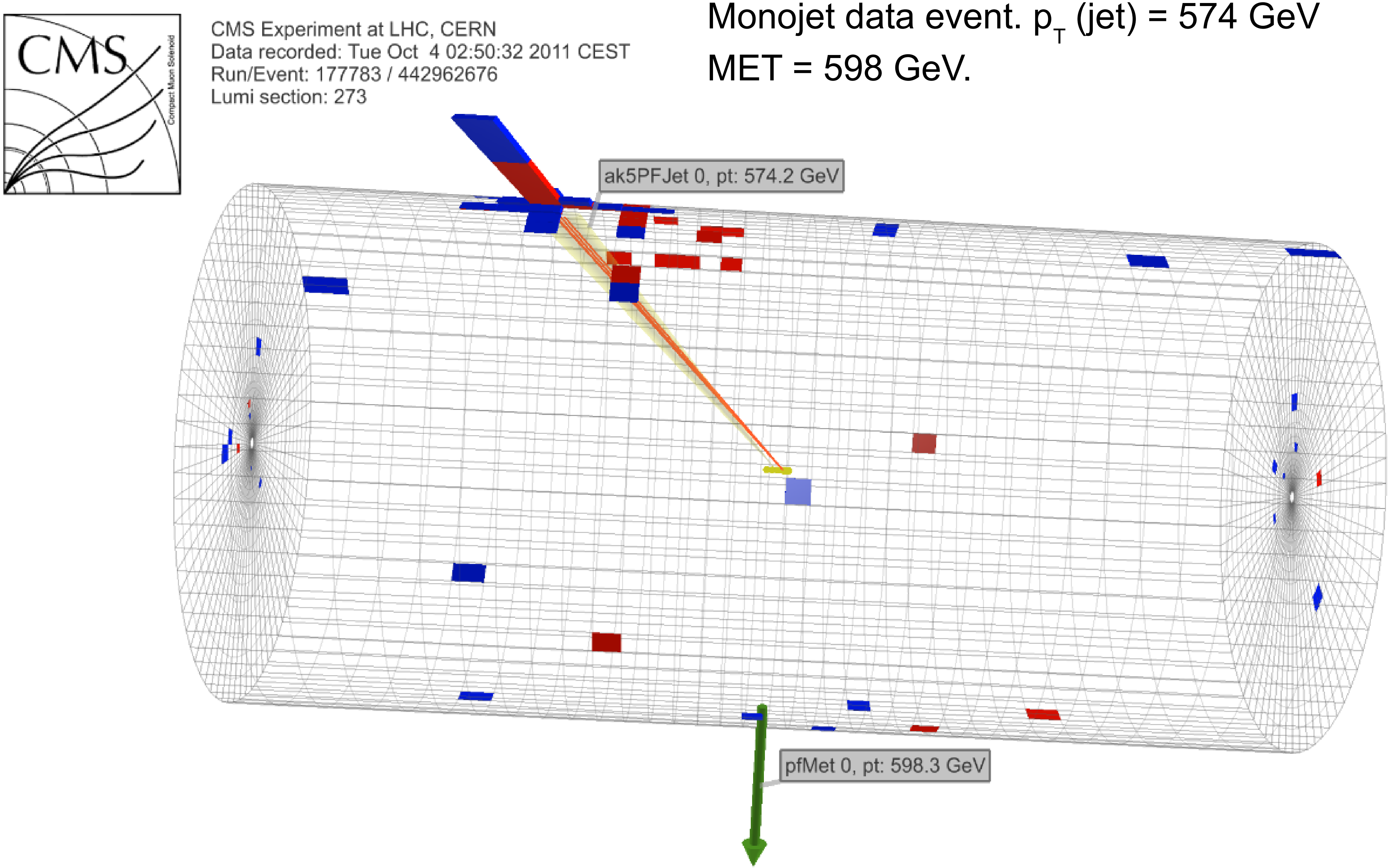


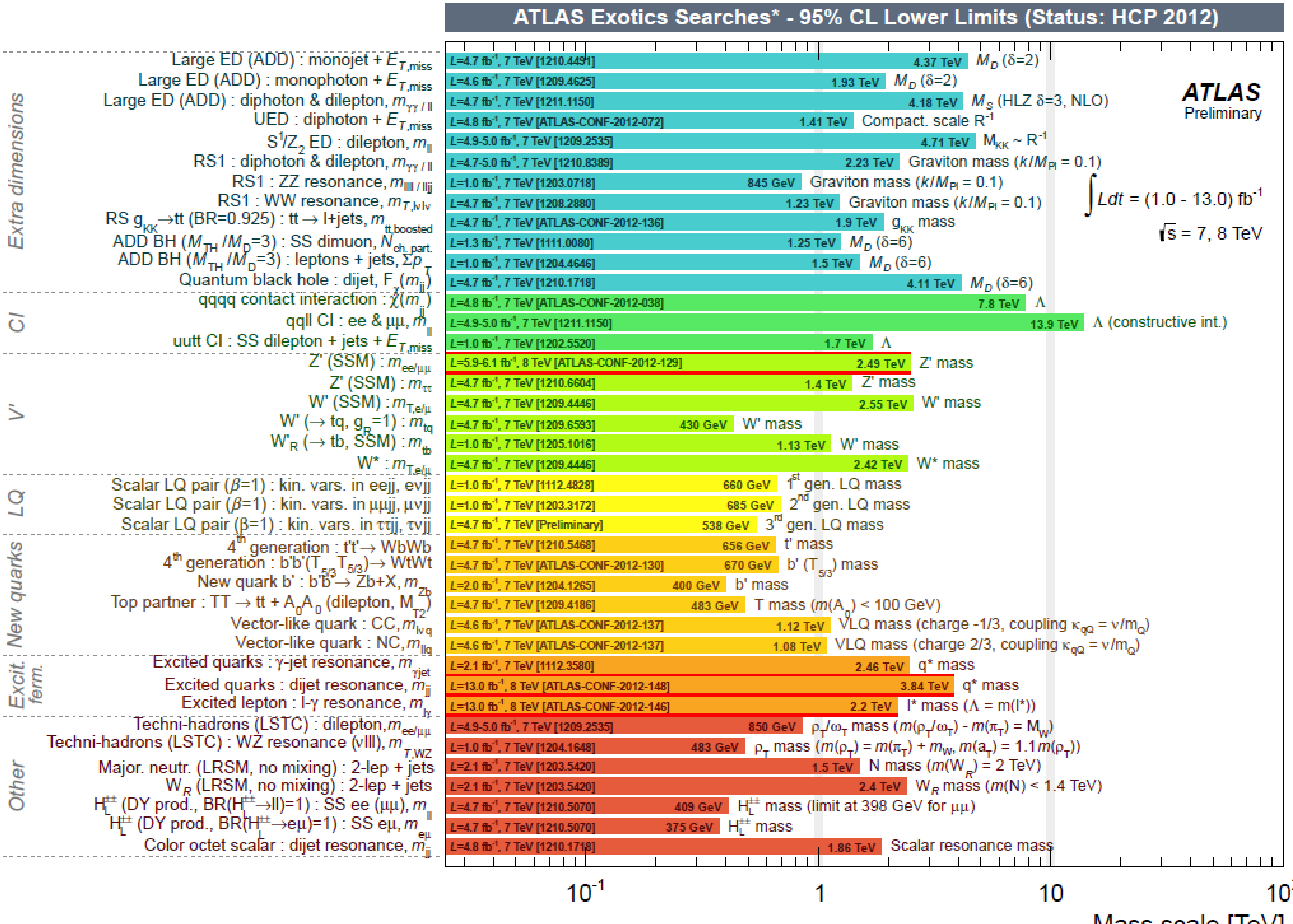
$$M_D^{n+2} \propto M_{\mathrm{Pl}}^2 R^{-n}$$

Search for dark matter and extradimenions with monojets

Monojet data event. p_T (jet) = 574 GeV

MET = 598 GeV.





*Only a selection of the available mass limits on new states or phenomena shown

Summary

- The LHC found a Higgs-like particle!!
- Apart from that, all measurements match the predictions of the Standard Model...

But to watch out for: Enhanced H $\rightarrow \gamma\gamma$ signal strength.

- Is the Higgs-like particle a SUSY Higgs?

It is possible! But no direct traces of SUSY have been found.

- ATLAS and CMS look for other interesting signs of new physics, but nothing found so far