SEARCH FOR NEW PHYSICS AT LARGE HADRON COLLIDER (CMS)

(Hope not last hadron collider)

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OUTLINE

- 1. Introduction
- 2. Standard Higgs boson
- 3. Supersymmetry(MSSM model)
- 4. New physics beyond the SM and the MSSM(EXOTICA)
- 4b. W_r boson and heavy neutrino
- 5. Conclusions

1.Introduction

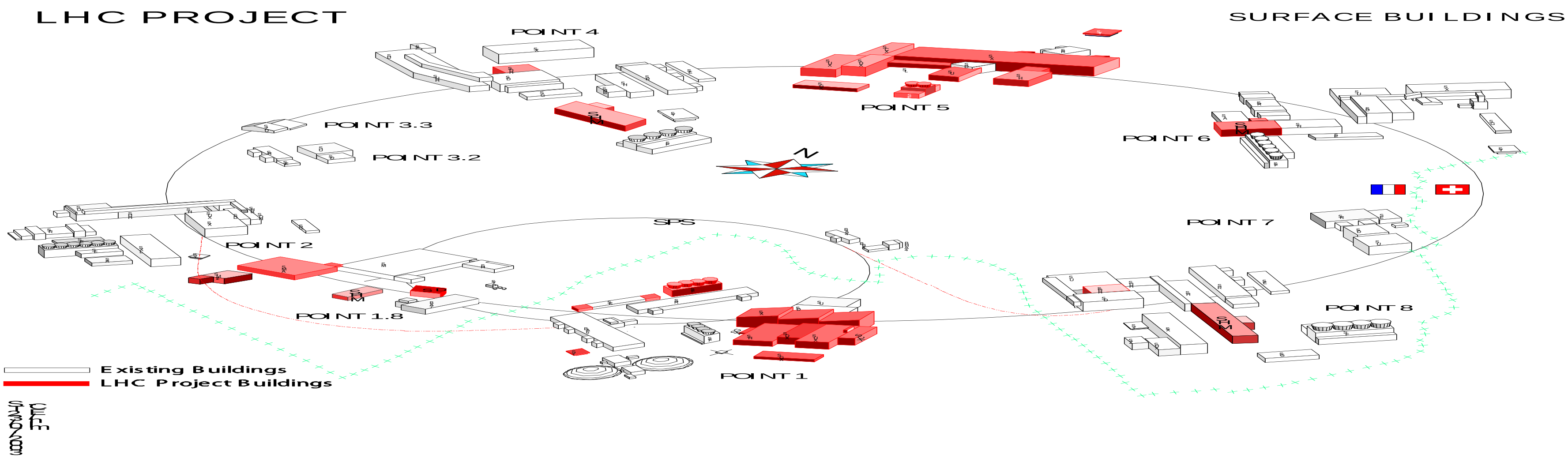
LHC(Large Hadron Collider)
Real start: 2010
Two proton beams with total energy
E = 7 TeV
Low luminosity stage with $L_{low} = 4*10^{33}$ $cm^{-2}s^{-1}$
Remember: Nev = sigma Lt
with total luminosity L_t = 4.7 fb^{-1} per 2011 year Remember: 1 fb = 10^{-39} cm^2s^{-1}
2012: Total energy 8 TeV and luminosity goal (15-20) fb^{-1}

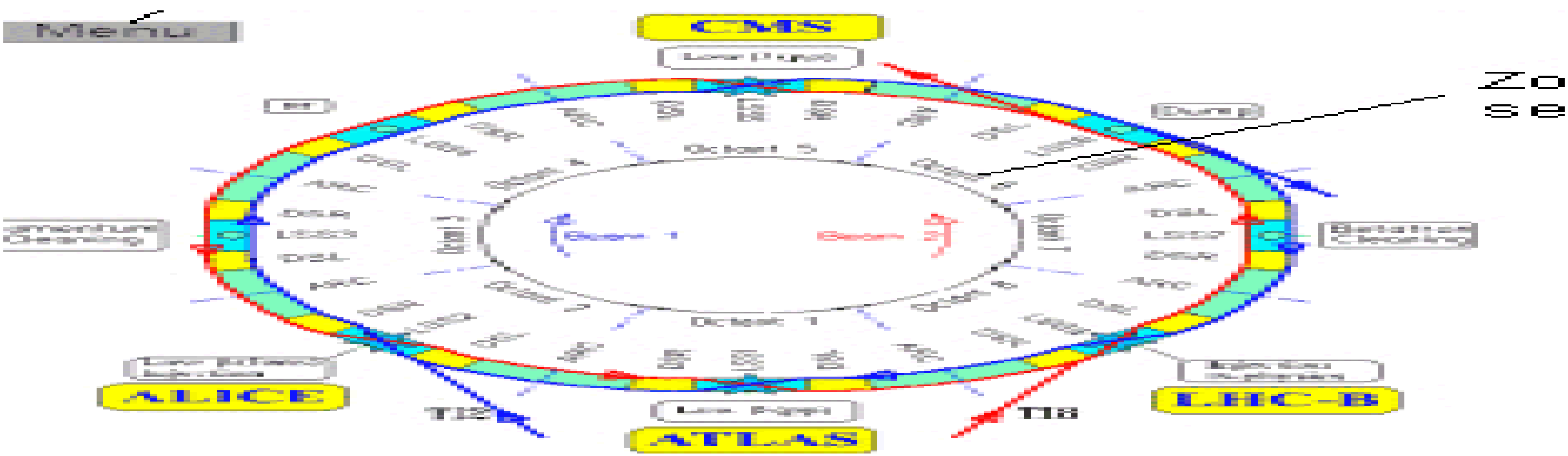
Two big detectors:
CMS(Compact Muon Solenoid)
ATLAS(A Toroidal LHC Apparatus)

In this talk we review

1. The search for Standard Higgs boson
2. The search for supersymmetry
3. The search for new physics beyond SM and MSSM

Perspective view of the LHC

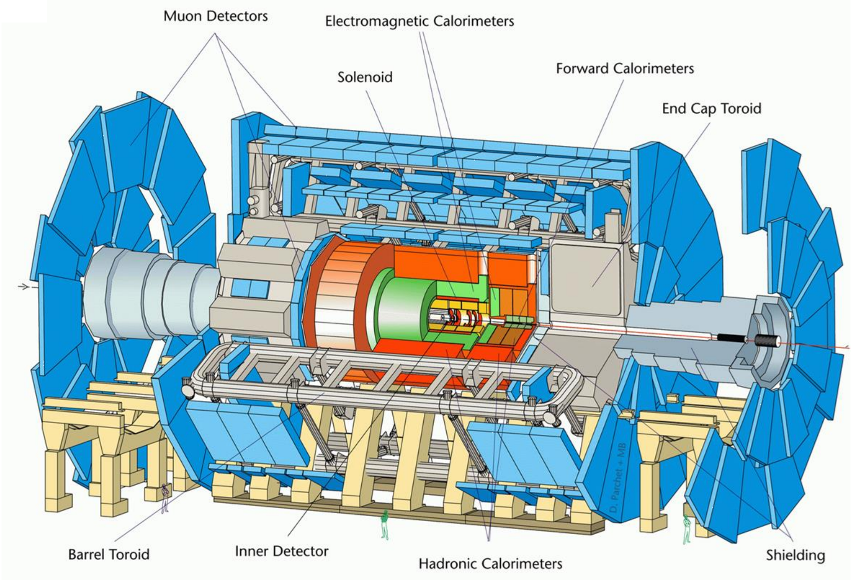




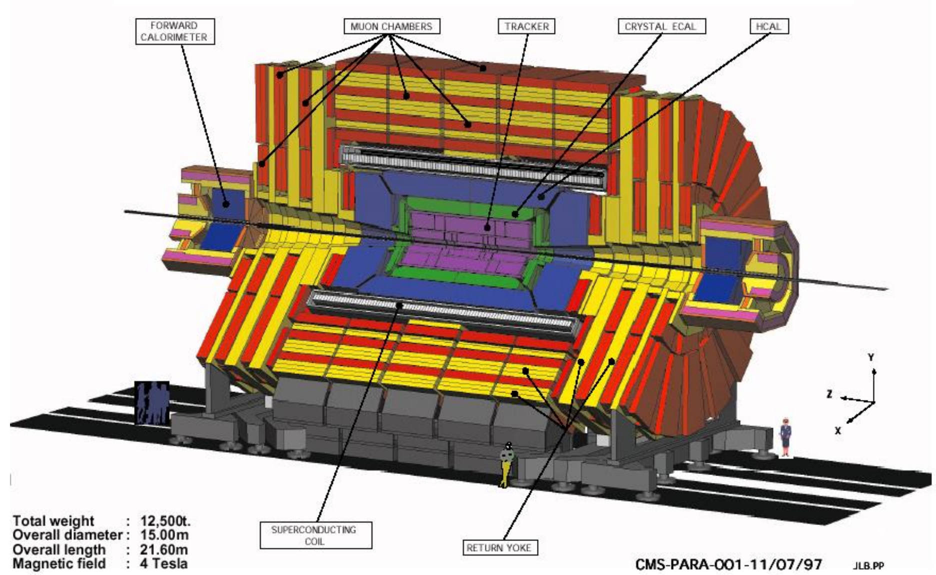
ATLAS and CMS Experiments

Large general-purpose particle physics detectors

A Large Toroidal LHC ApparatuS



Compact Muon Solenoid



Total weight	**7000 t**
Overall diameter	**25 m**
Barrel toroid length	**26 m**
End-cap end-wall chamber span	**46 m**
Magnetic field	**2 Tesla**

Total weight	**12 500 t**
Overall diameter	**15.00 m**
Overall length	**21.6 m**
Magnetic field	**4 Tesla**

Detector subsystems are designed to measure:
energy and momentum of γ ,e, μ, jets, missing E_T up to a few TeV

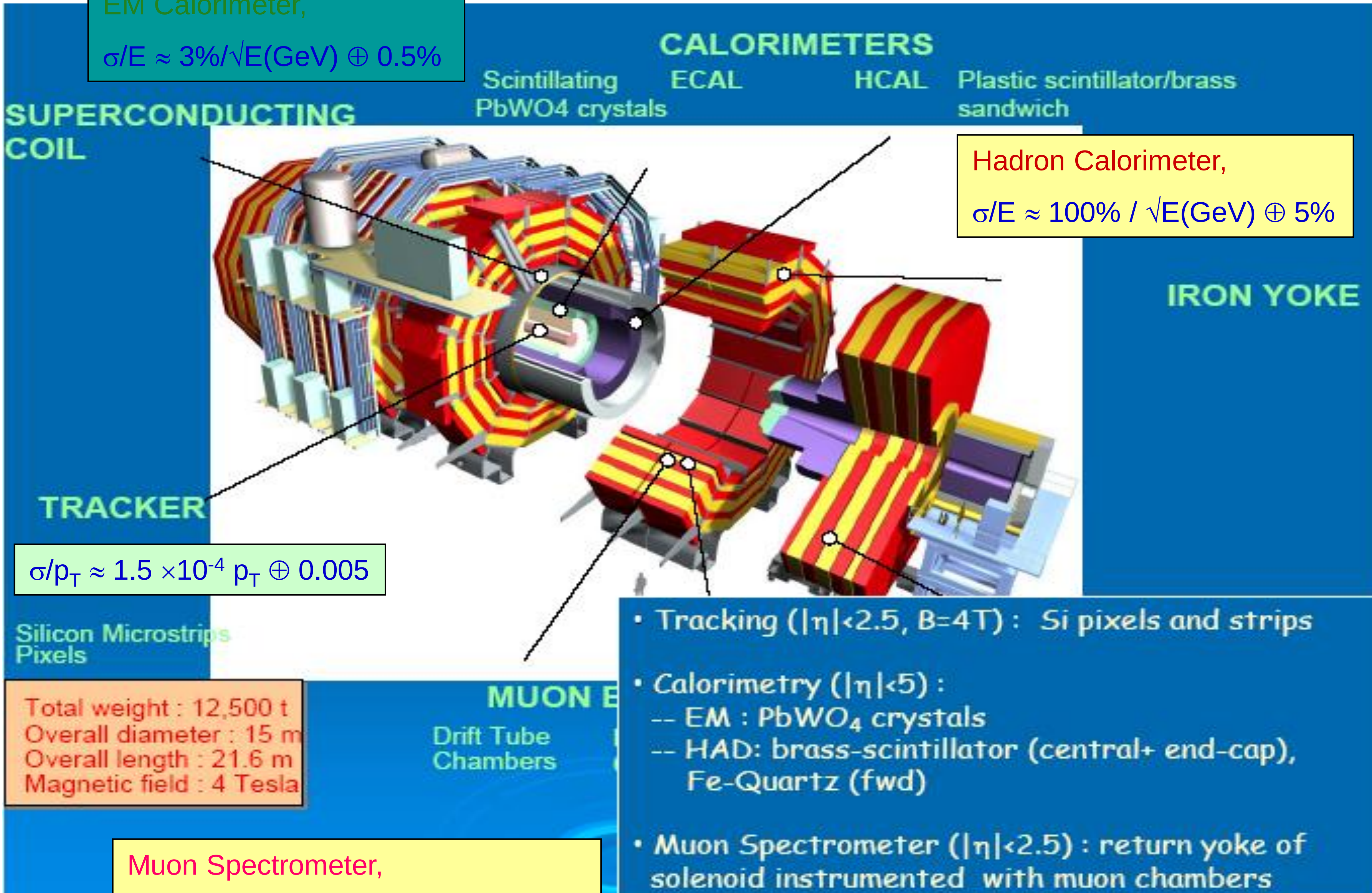
Compact Muon Solenoid (CMS) DETECTOR

EM Calorimeter,

$\sigma/E \approx 3\%/\sqrt{E(GeV)} \oplus 0.5\%$

Hadron Calorimeter,

$\sigma/E \approx 100\% / \sqrt{E(GeV)} \oplus 5\%$



$\sigma/p_T \approx 1.5 \times 10^{-4}\, p_T \oplus 0.005$

Muon Spectrometer,

$\sigma/p_T \approx 5\%$ at 1 TeV/c (from Tracker)

A Toroidal LHC AppartuS (ATLAS) DETECTOR

EM Calorimeters, $\sigma/E \approx 10\%/\sqrt{E(\mathrm{GeV})} \oplus 0.7\%$

excellent electron/photon identification

Good *E* resolution (e.g., $H \to \gamma\gamma$)

Precision Muon Spectrometer,

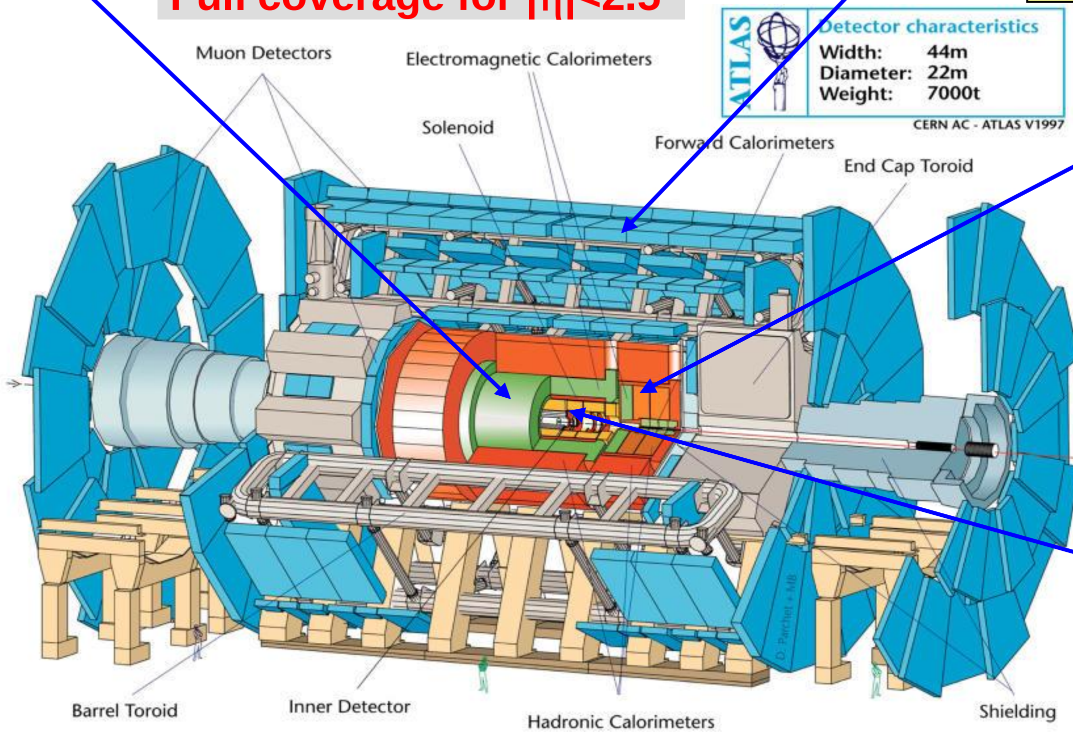
$\sigma/p_T \approx 10\%$ at 1 TeV/c

Fast response for trigger

Good *p* resolution

(e.g., $A/Z' \to \mu\mu$, $H \to 4\mu$)

Full coverage for $|\eta|<2.5$



Hadron Calorimeters,

$\sigma/E \approx 50\% / \sqrt{E(\mathrm{GeV})} \oplus 3\%$

Good jet and E_T miss performance

(e.g., $H \to \tau\tau$)

Inner Detector:

Si Pixel and strips (SCT) &

Transition radiation tracker (TRT)

$\sigma/p_T \approx 5 \times 10^{-4}\, p_T \oplus 0.001$

Good impact parameter res.

$\sigma(d_0)=15\mu m@20GeV$ (e.g. $H \to bb$)

Magnets: solenoid (Inner Detector) 2T, air-core toroids (Muon Spectrometer) ~0.5T

Higgs boson search

- The existence of the Higgs boson is the direct consequence of the renormalizability of electroweak interactions and vice versa

So the discovery of the Higgs boson last nondiscovered ingredient of Standard Model will be the triumph of the renormalizability approach which severely restricts the form of possible interactions and fixes Lagrangian up to several arbitrary terms with D =<4

2. Standard Higgs boson search

In $SU(3) \otimes SU(2) \otimes U(1)$ Standard Model

$H(X) = (H_1(x), H_2(x))$ Higgs field is $SU(2)_L$ doublet

In unitare gauge $H(x) = (0, \frac{v}{\sqrt{2}} + \frac{H(x)}{\sqrt{2}})$, v=242GeV

The most important interactions are:

$$\frac{2M_W^2}{v} HW_\mu^+ W + \frac{M_Z^2}{v} Z_\mu Z^\mu - \frac{m_t}{v} H\bar{t}t - \frac{m_\tau}{v} \bar{\tau}\tau$$

Experimental bounds on the Higgs boson mass

M_h >114.4 GeV LEP2 bound

M_h <162 GeV LEP1 + rad.cor.

Higgs boson mass bounds

Theoretical bounds :

1. Unitarity bound : $m_H < 700$ GeV
2. Vacuum stability bound: $m_H > 135$ GeV
3. Absence of Landau pole singularity:

   $m_H < 170$ GeV

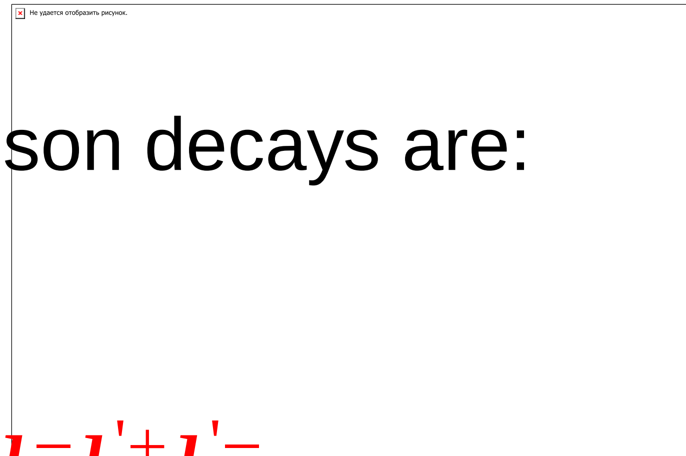
   (for $\Lambda = 10^{12}$ GeV)

So there are several indications that the Higgs boson is relatively light . Moreover,

in the MSSM model the lightest Higgs boson

$m_h < 140$ GeV

Higgs boson decays



The most important Higgs boson decays are:

$$H \to \gamma\gamma$$

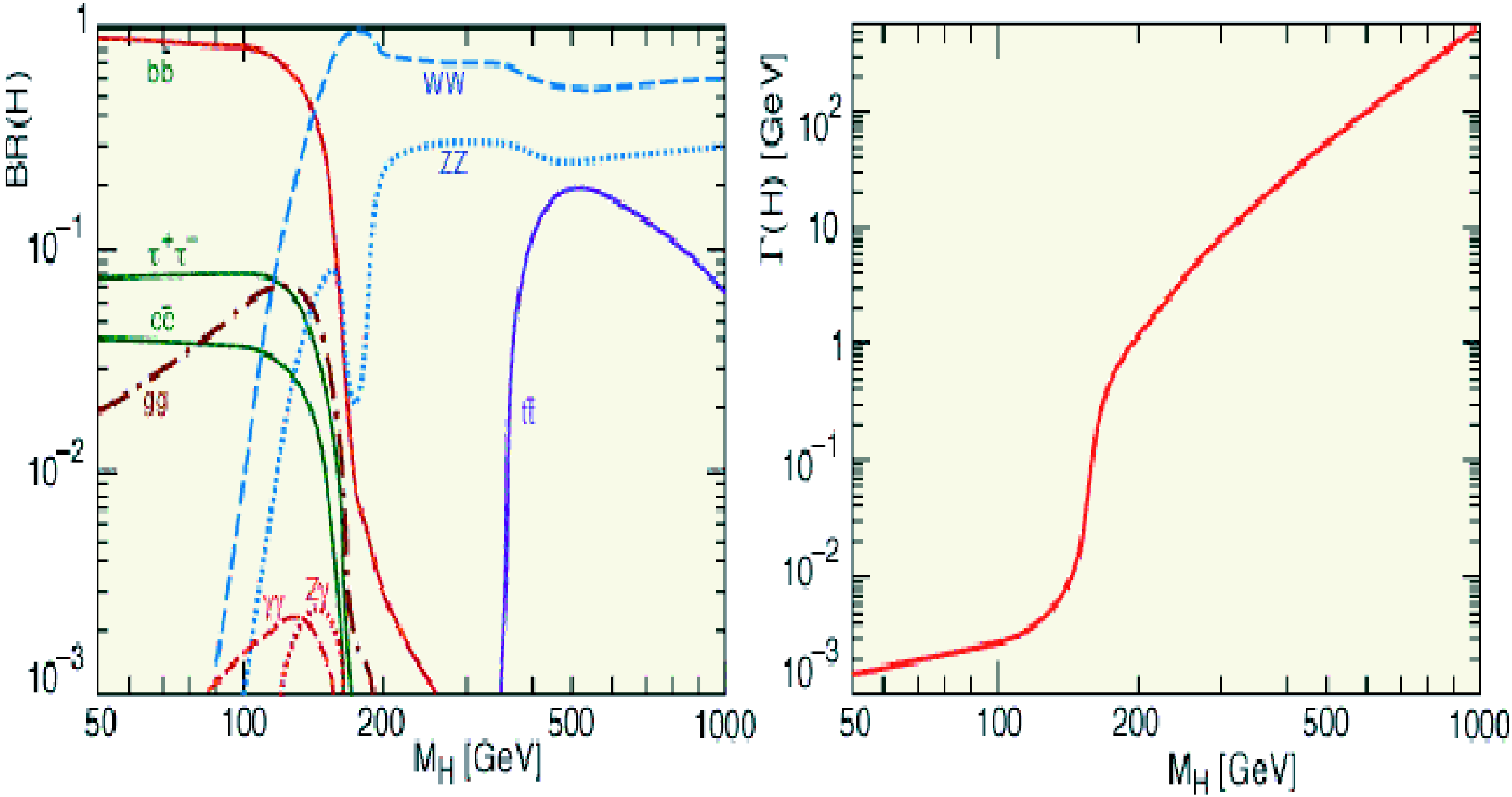
$$H \to ZZ^{*}/ZZ \to l^{+}l^{-}l'^{+}l'^{-}$$

$$H \to WW^{*}/WW \to l^{+}\upsilon l'^{-}\upsilon$$

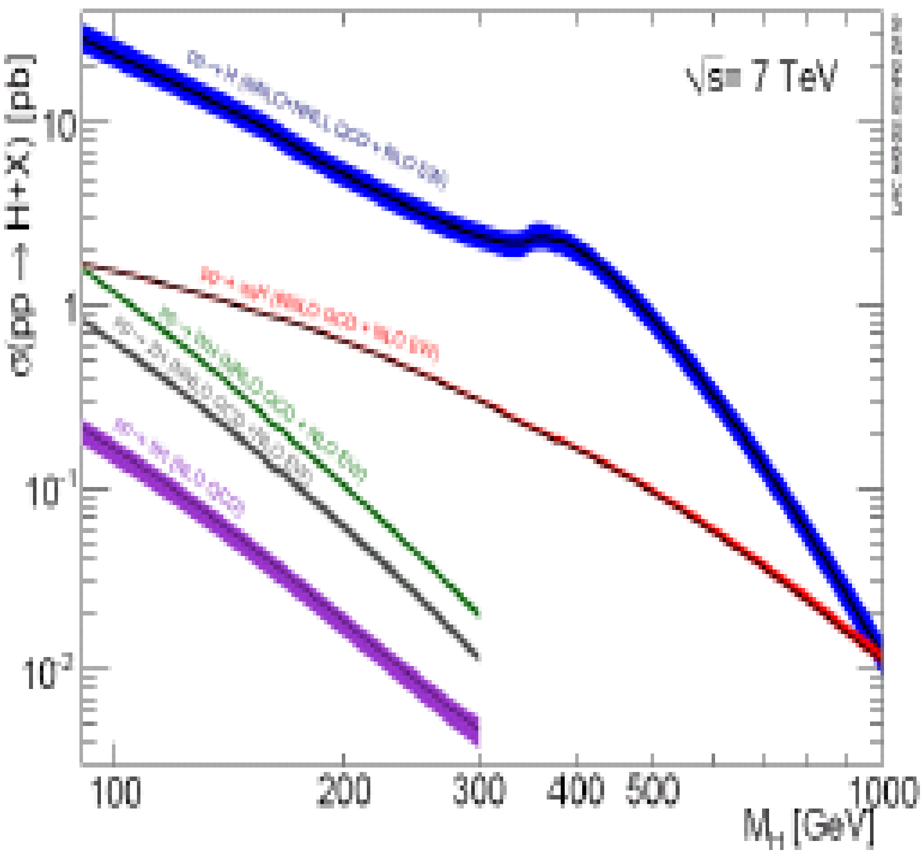
$$H \to b\bar{b}$$

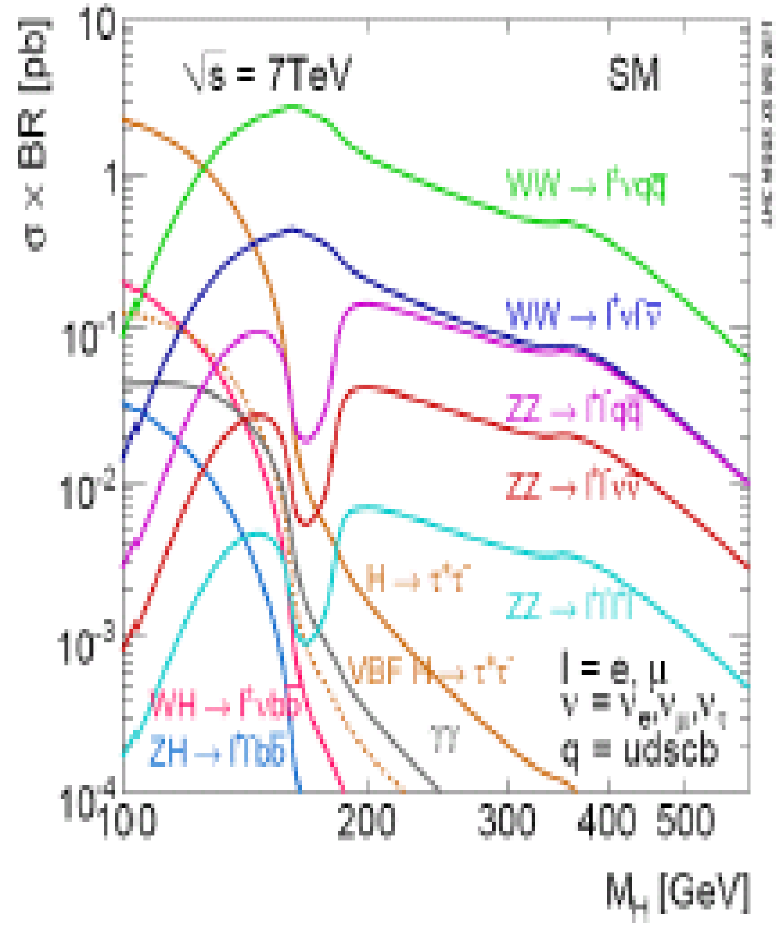
$$H \to \tau\bar{\tau}$$

Branching ratios and decay width of the SM Higgs boson



Branchings and cross sections





Higgs boson production mechanisms

1. Gluon fusion: $gg \to H$ (the main mechanism)

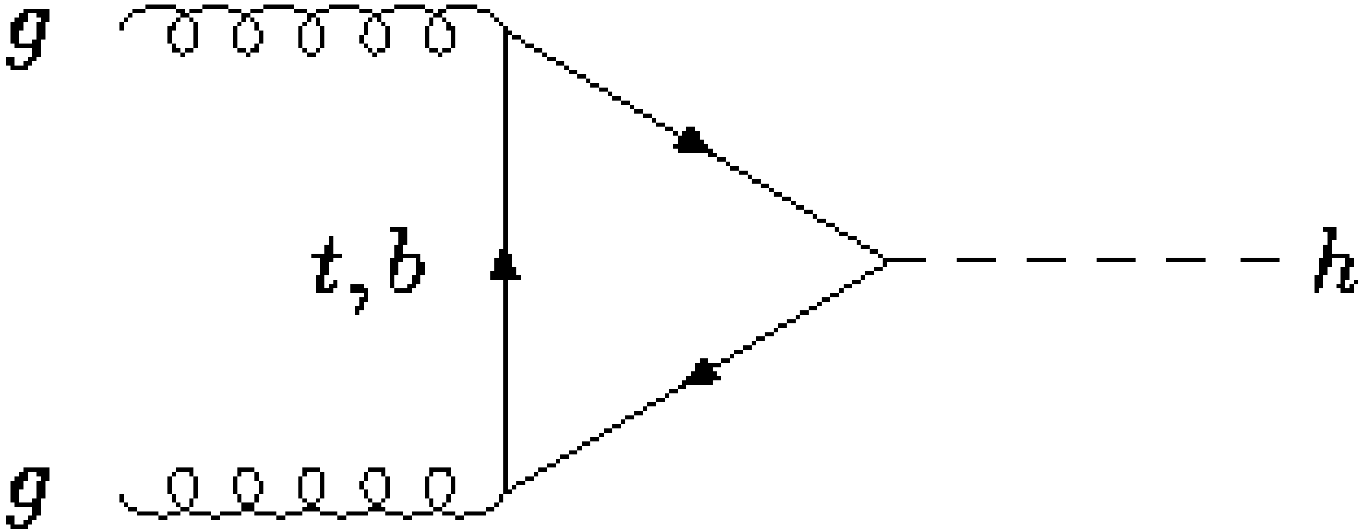
2. WW, ZZ fusion: $W^+ W^-$, ZZ → H

3. Higgs-strahlung off W, Z : qqW,Z → W +H, Z +H

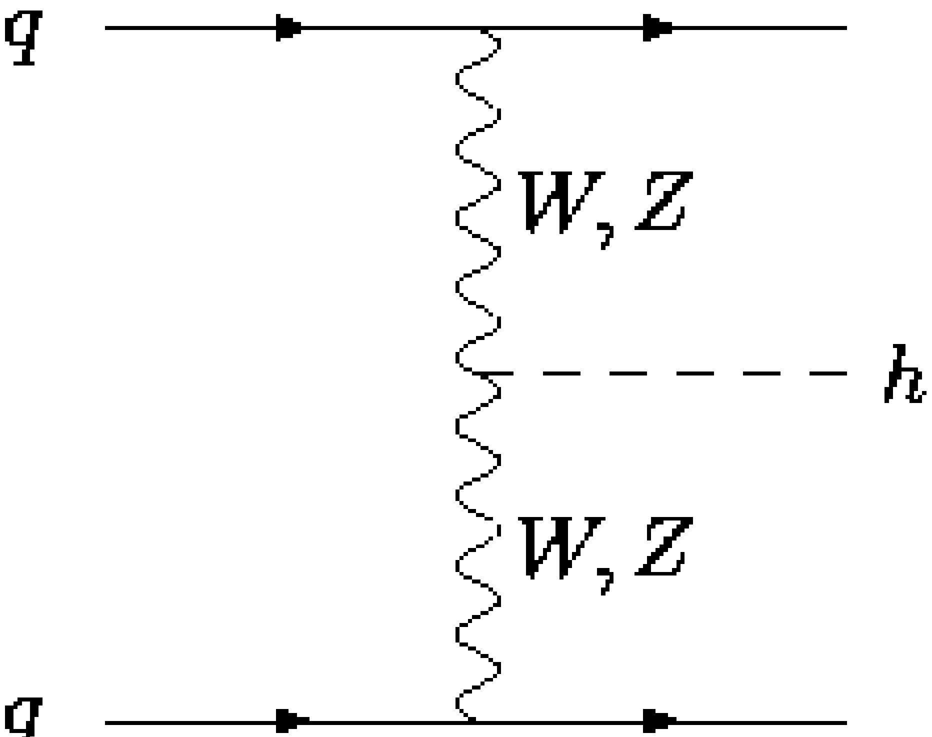
4. Higgs bremsstrahlung off top quark: qq, gg →tt +H

For m_H = 120 GeV Higgs boson production cross section is around 45 pb.

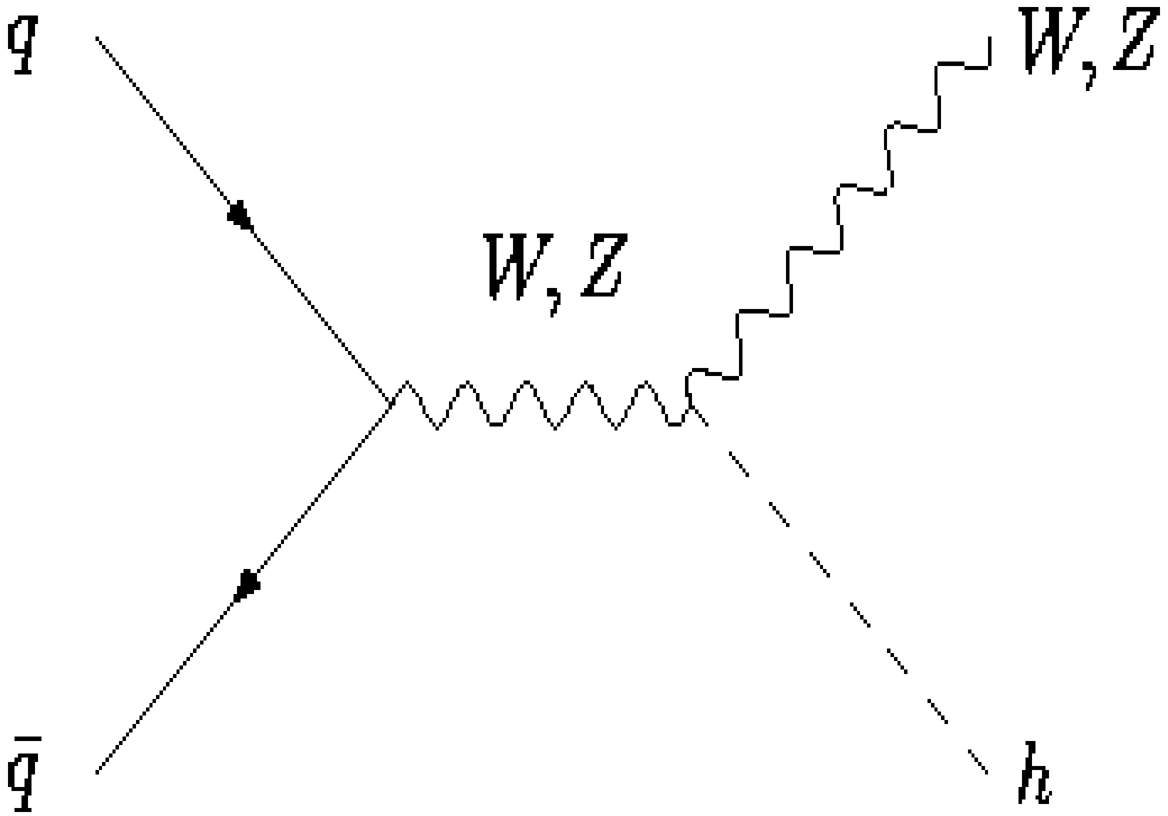
Gluon fusion diagram



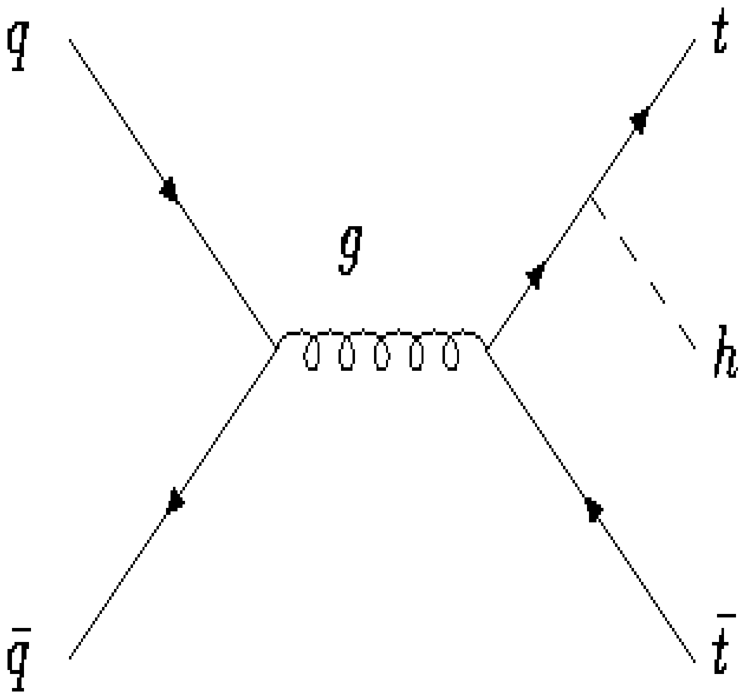
Weak boson fusion diagram

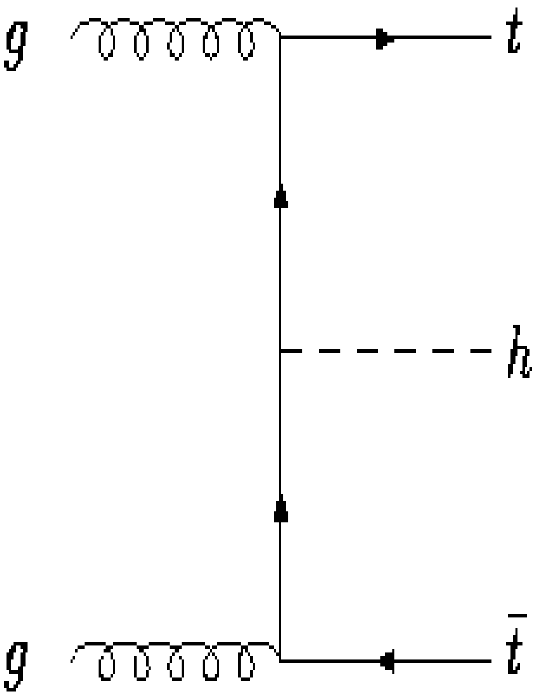


Higgs-strahlung off W and Z

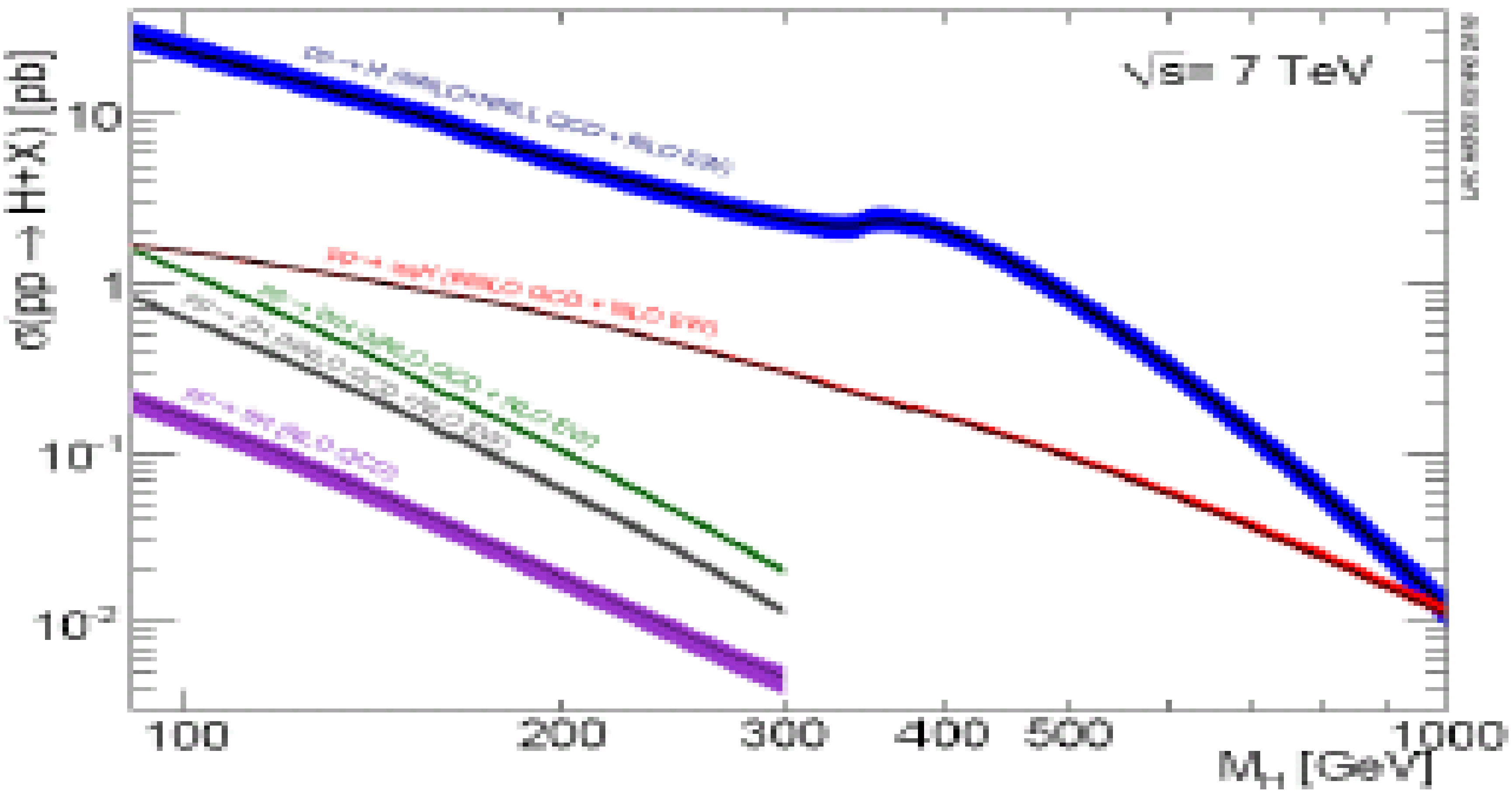


Higgs bremsstrahlung off top quark





Higgs boson production cross section at the LHC



Signatures used for Higgs search

- H →WW* →2l2nu
- H→WW* →2l2q
- H→ZZ*→4l
- H--.ZZ*-.2l2q
- H→ZZ*→2l2tau
- H→ZZ*→2l2nu
- H→2l2jets
- H→gamma gamma
- H→bb

Higgs Search Channels in CMS

	Channel	m_H range (GeV)	Luminosity (fb^{-1})	Sub-channels	m_H resolution
new	$H \to \gamma\gamma$	110–150	4.8	2	1–2%
	$H \to \tau\tau \to e\tau_h/\mu\tau_h/e\mu + X$	110–145	4.6	9	20%
new	$H \to \tau\tau \to \mu\mu + X$	110–140	4.5	3	20%
new	$WH \to e\mu\tau_h/\mu\mu\tau_h + \nu's$	100–140	4.7	2	20%
	$(W/Z)H \to (e\nu/\mu\nu/ee/\mu\mu/\nu\nu)(bb)$	110–135	4.7	5	10%
	$H \to WW^* \to 2\ell 2\nu$	110–600	4.6	5	20%
new	$WH \to W(WW^*) \to 3\ell 3\nu$	110–200	4.6	1	20%
	$H \to ZZ^{(*)} \to 4\ell$	110–600	4.7	3	1–2%
	$H \to ZZ^{(*)} \to 2\ell 2q$	130–164 200–600	4.6	6	3% 3%
	$H \to ZZ \to 2\ell 2\tau$	190–600	4.7	8	10–15%
	$H \to ZZ \to 2\ell 2\nu$	250–600	4.6	2	7%

H→WW*→2l2nu

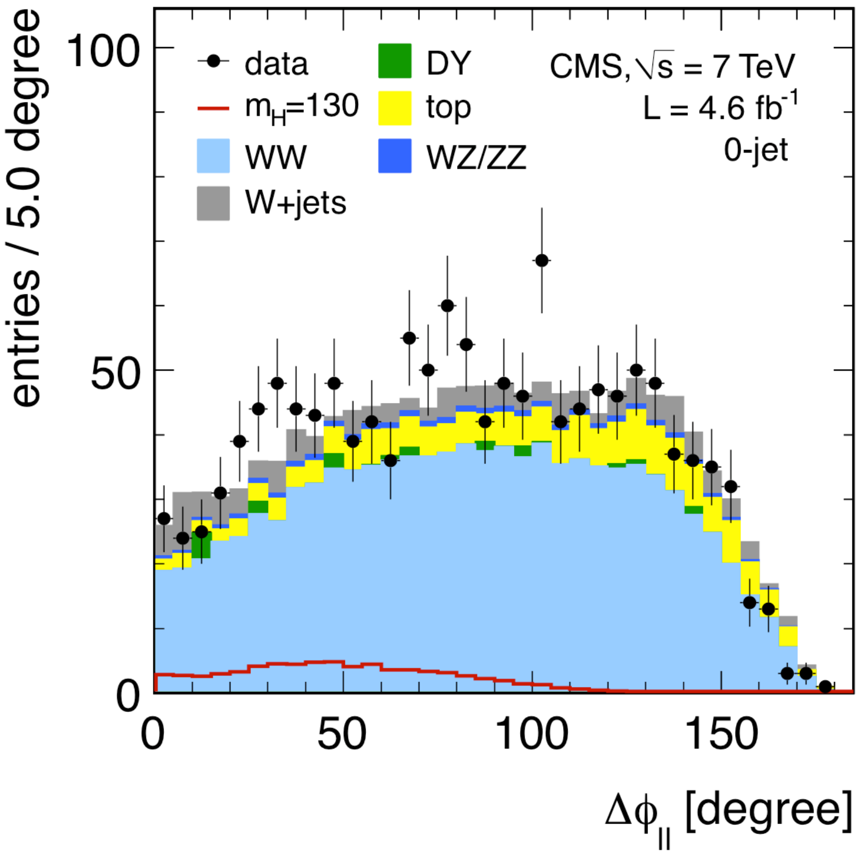
- For L =4.7fb^{-1}

in SM at 95% C.L. Higgs boson is excluded

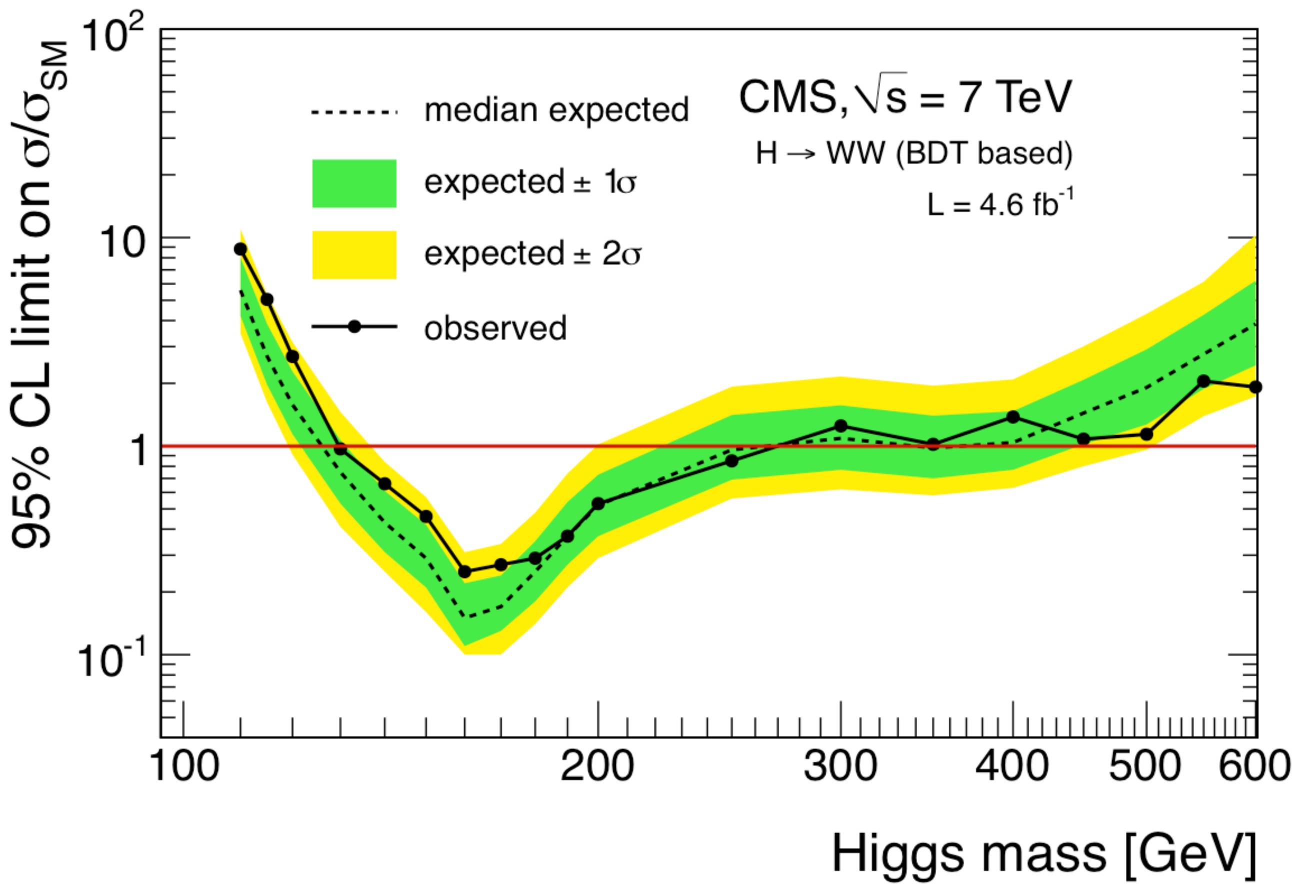
In the mass range [129 – 270] GeV

ATLAS → [130, 260] GeV are excluded

Distribution on dilepton angle



Limit on SM Higgs boson mass



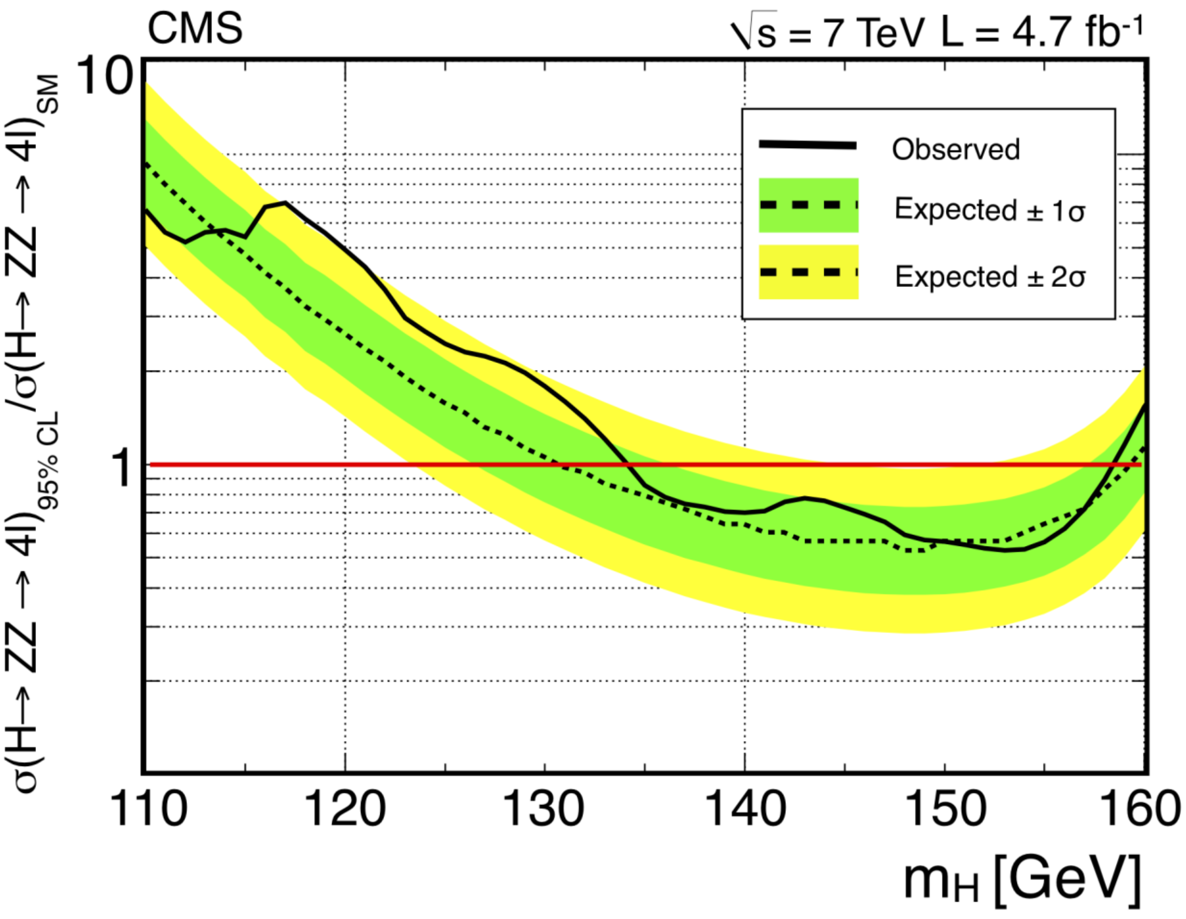
$H \to ZZ^* \to 4l$

Higgs in SM is excluded for [134 – 158], [180 – 305], [340 – 465] GeV mass region at 95% C.L. for $L=4.7fb^{-1}$

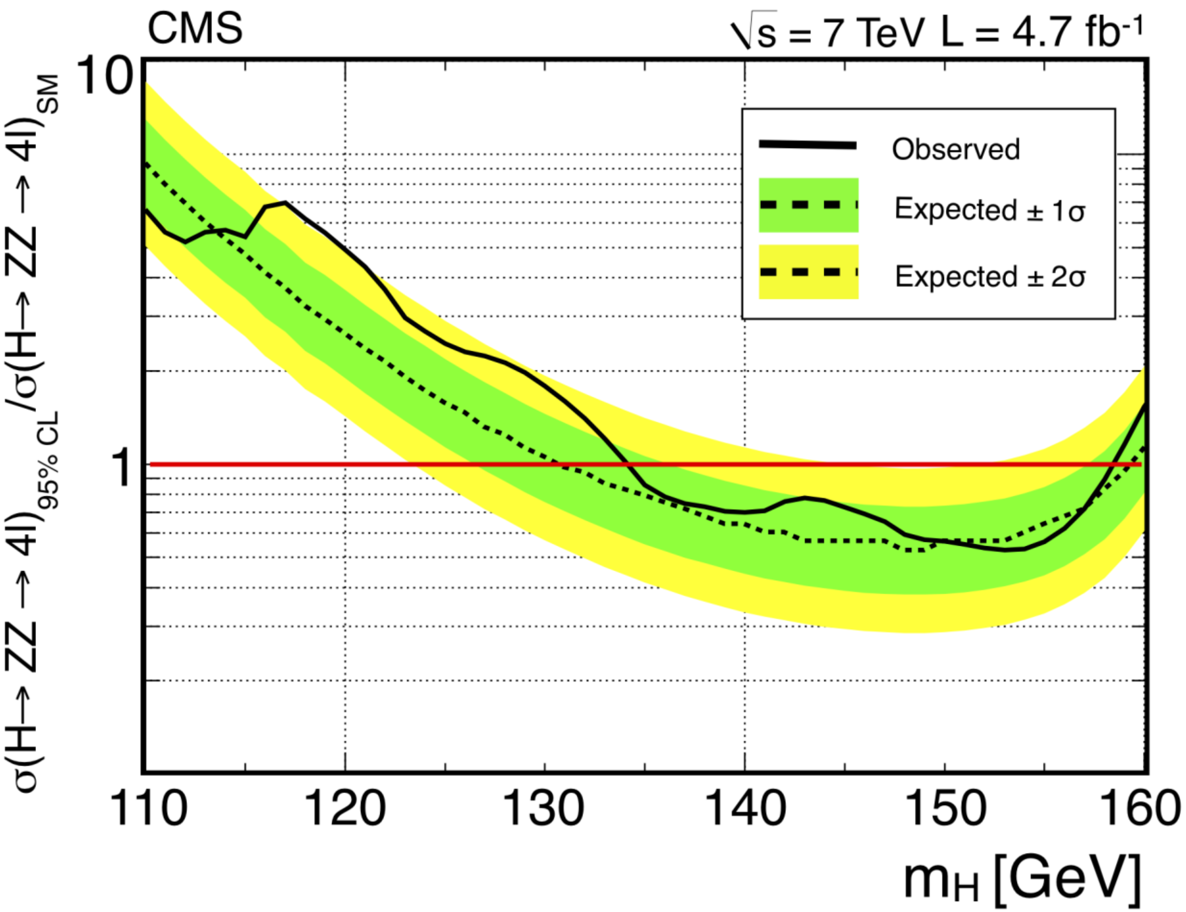
Small excesses of events around 119, 126 and 320 GeV

ATLAS → [134,156], [182, 233], [256, 265], [268, 415] are excluded

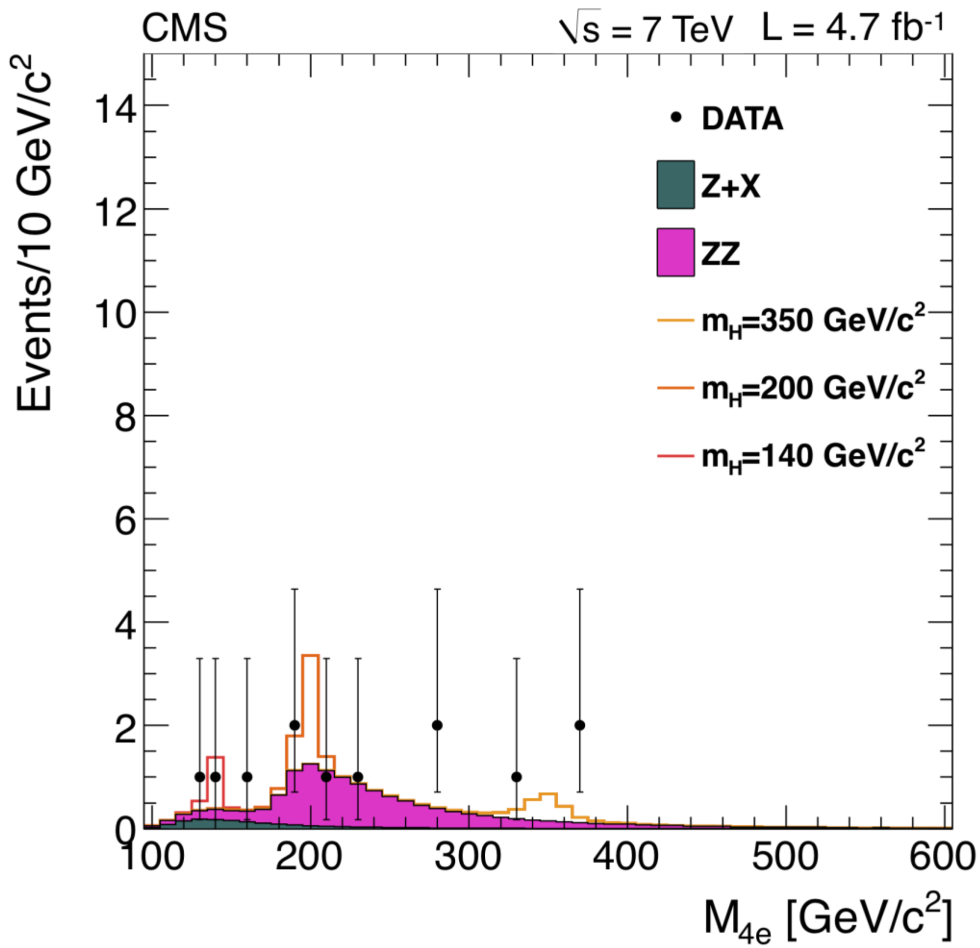
Limit for SM Higgs



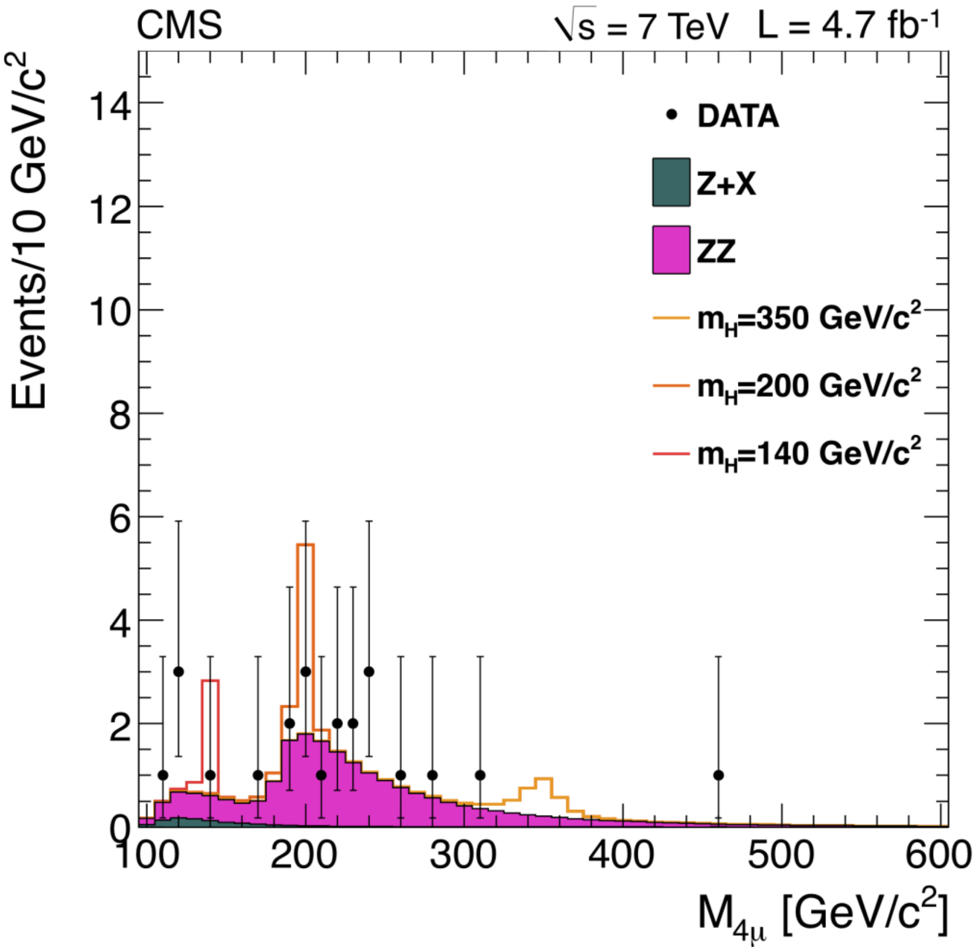
Limit for SM Higgs



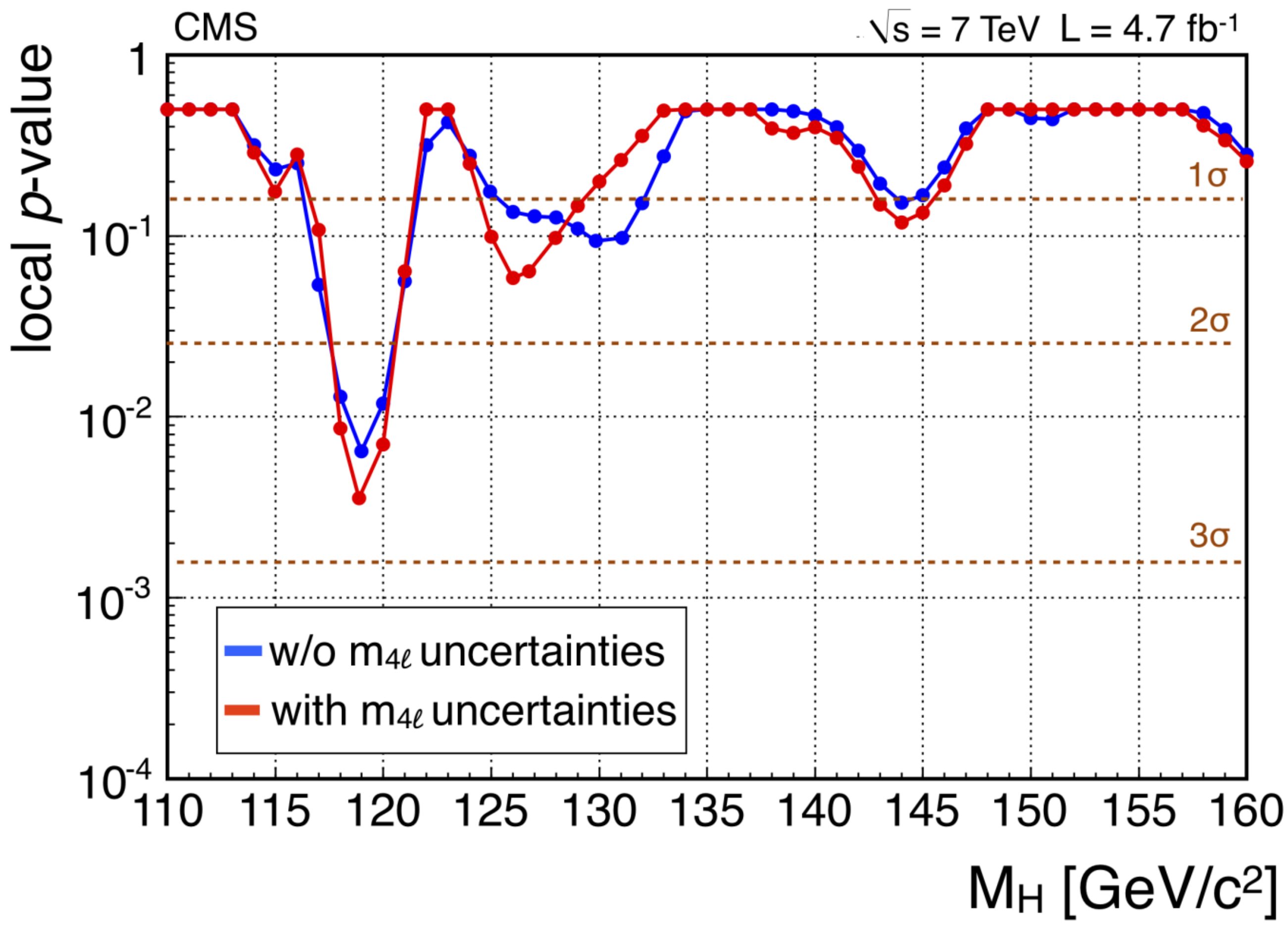
M(4e) invariant mass distribution



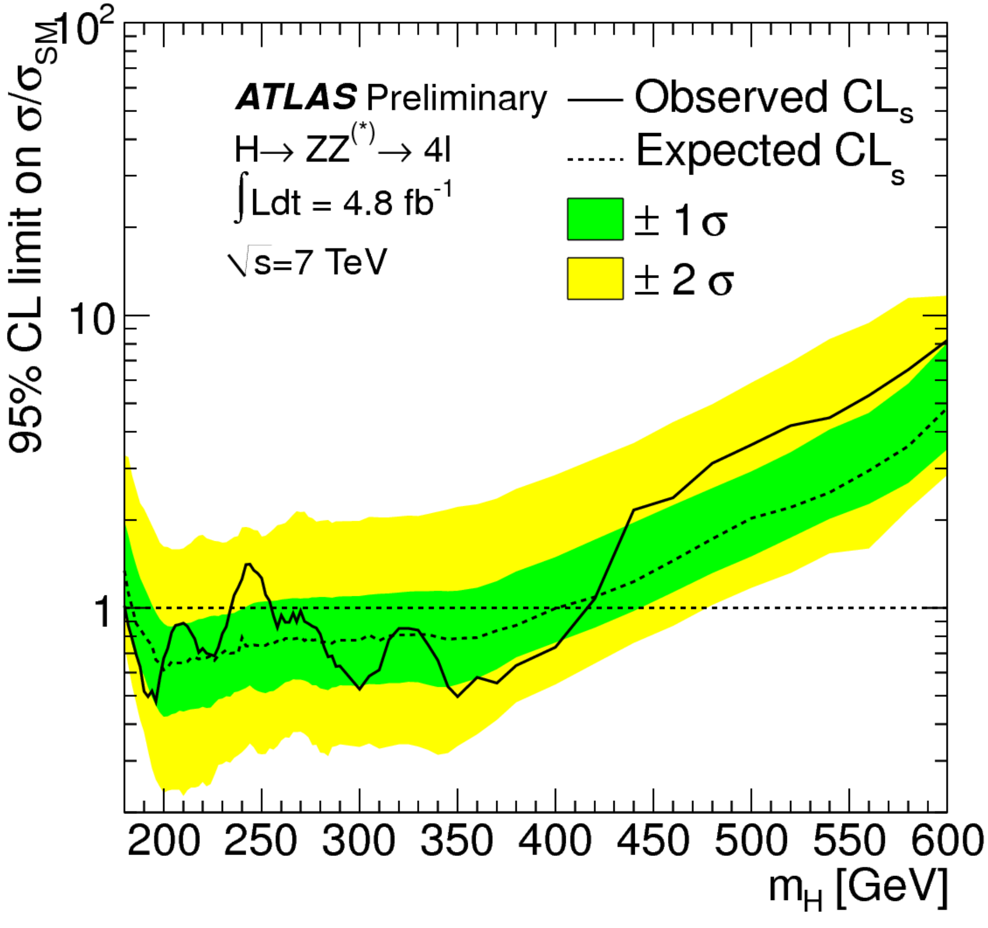
M(4mu) invariant vass distribution



P-values for Higgs to 4l mode



ATLAS 4l exclusion plot

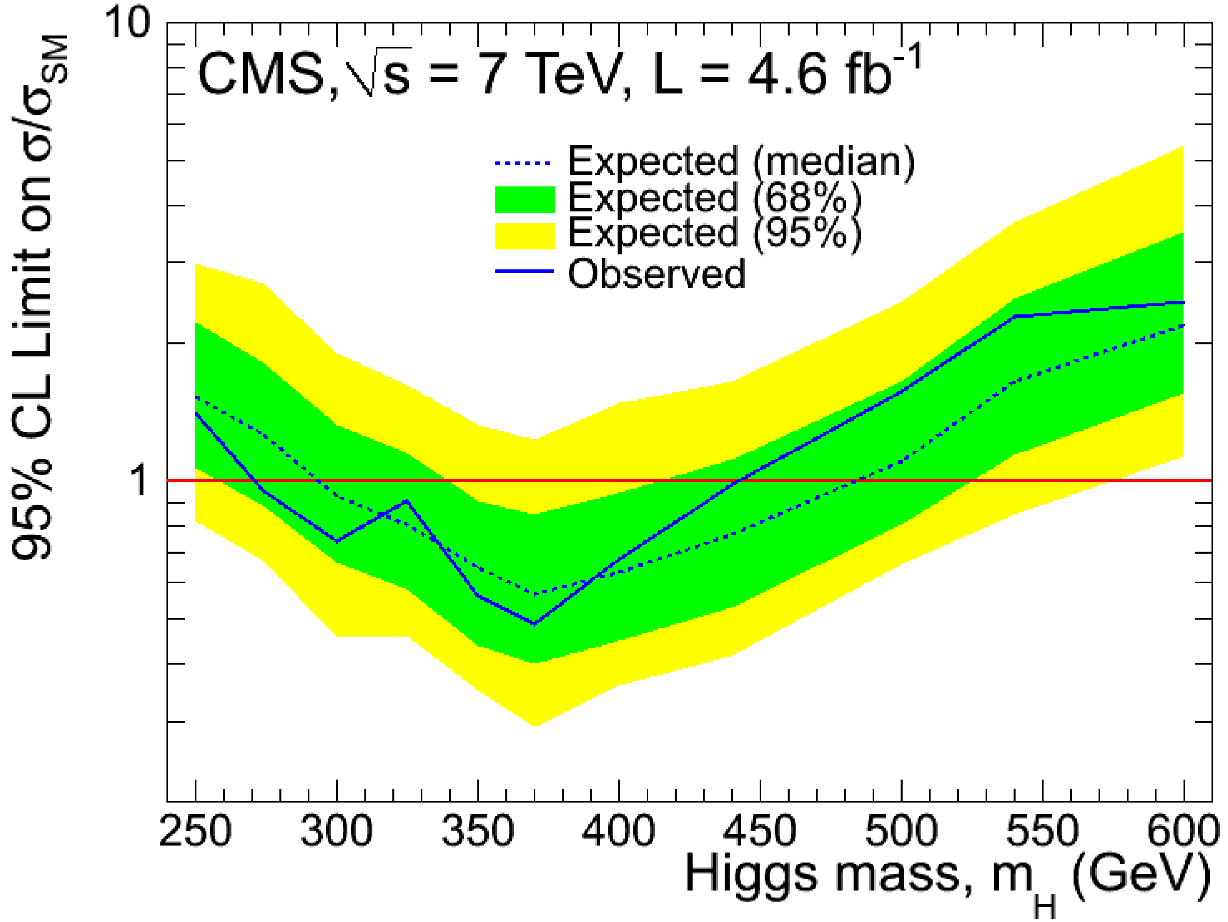


H→ZZ*→2l2nu

For L=4.7fb^{-1} SM Higgs is excluded for
[270 – 440] GeV region at 95% C.L.

ATLAS → [320, 560] GeV Higgs boson exclusion region

SM boson Higgs mass limit



H→ZZ→2l2q

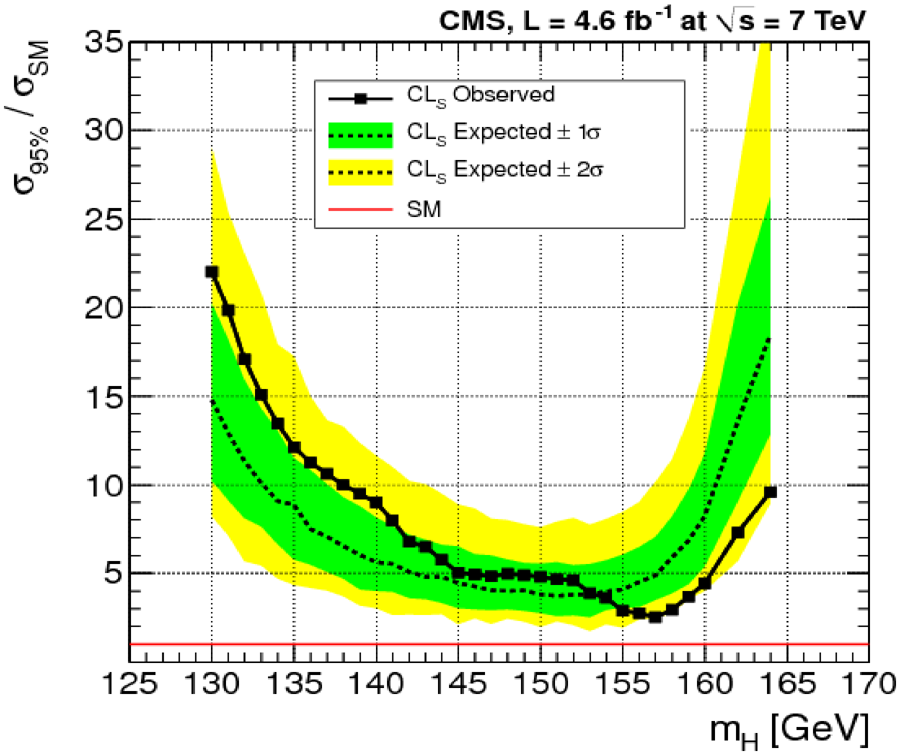
Bound on Higgs boson cross section

In [130 – 600] GeV mass region at 95%C.L.

ATLAS →

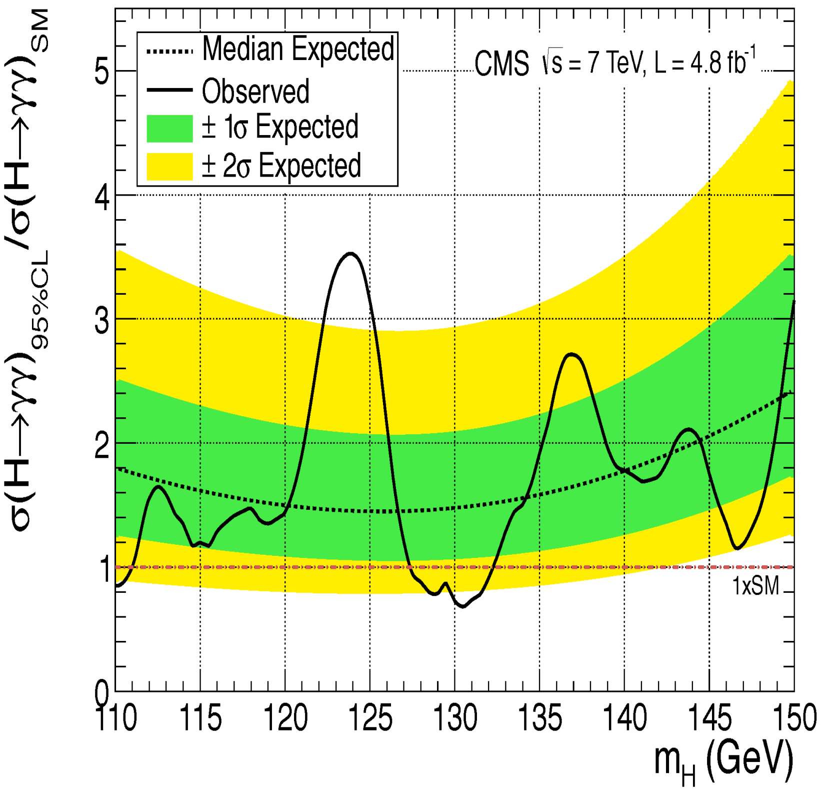
[300, 310], [360,400]

are excluded

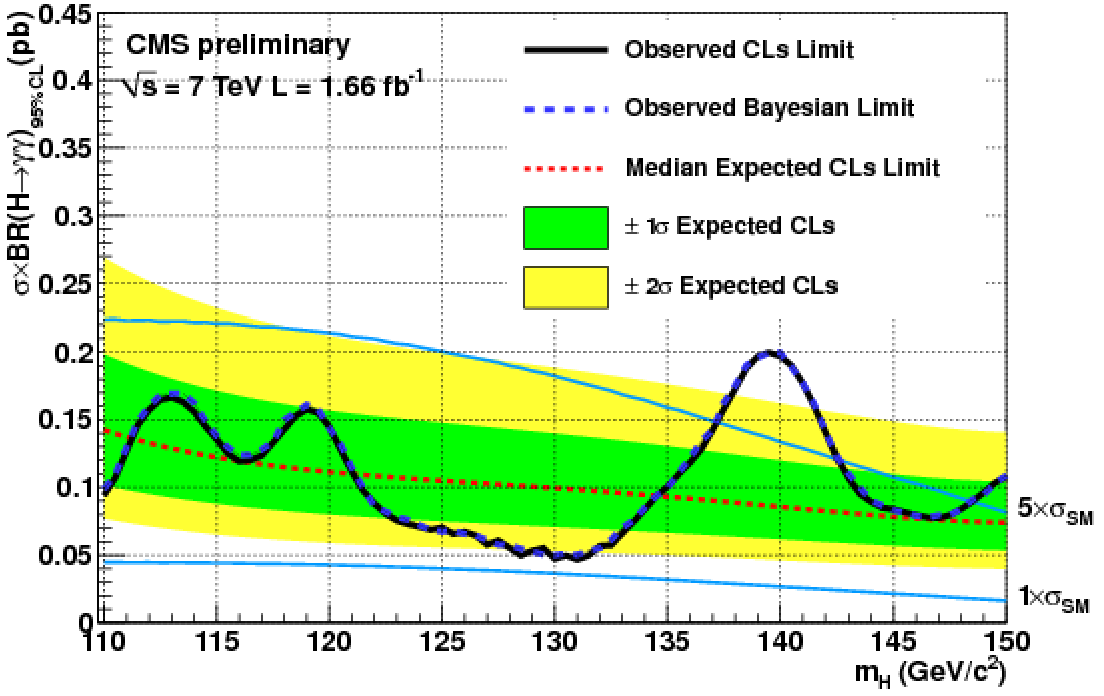


H→gamma gamma

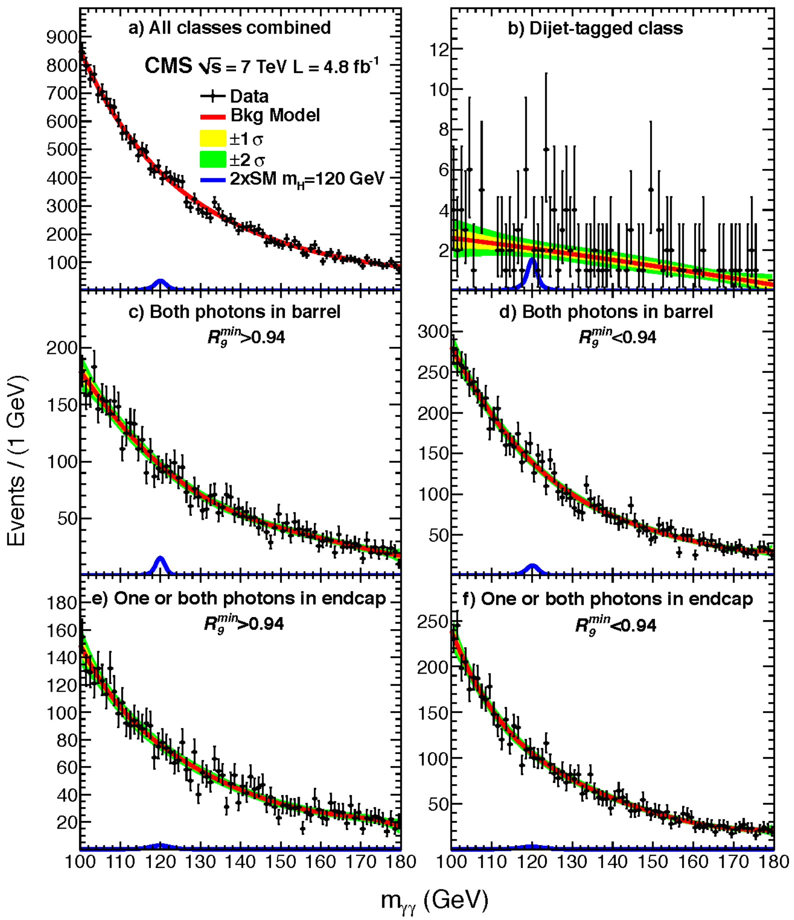
- SM Higgs is excluded for [128, 132] GeV region. Excess of events at 124 GeV
- ATLAS → [113, 115],
- [134.5, 136] are excluded
- excess at 126.5 GeV



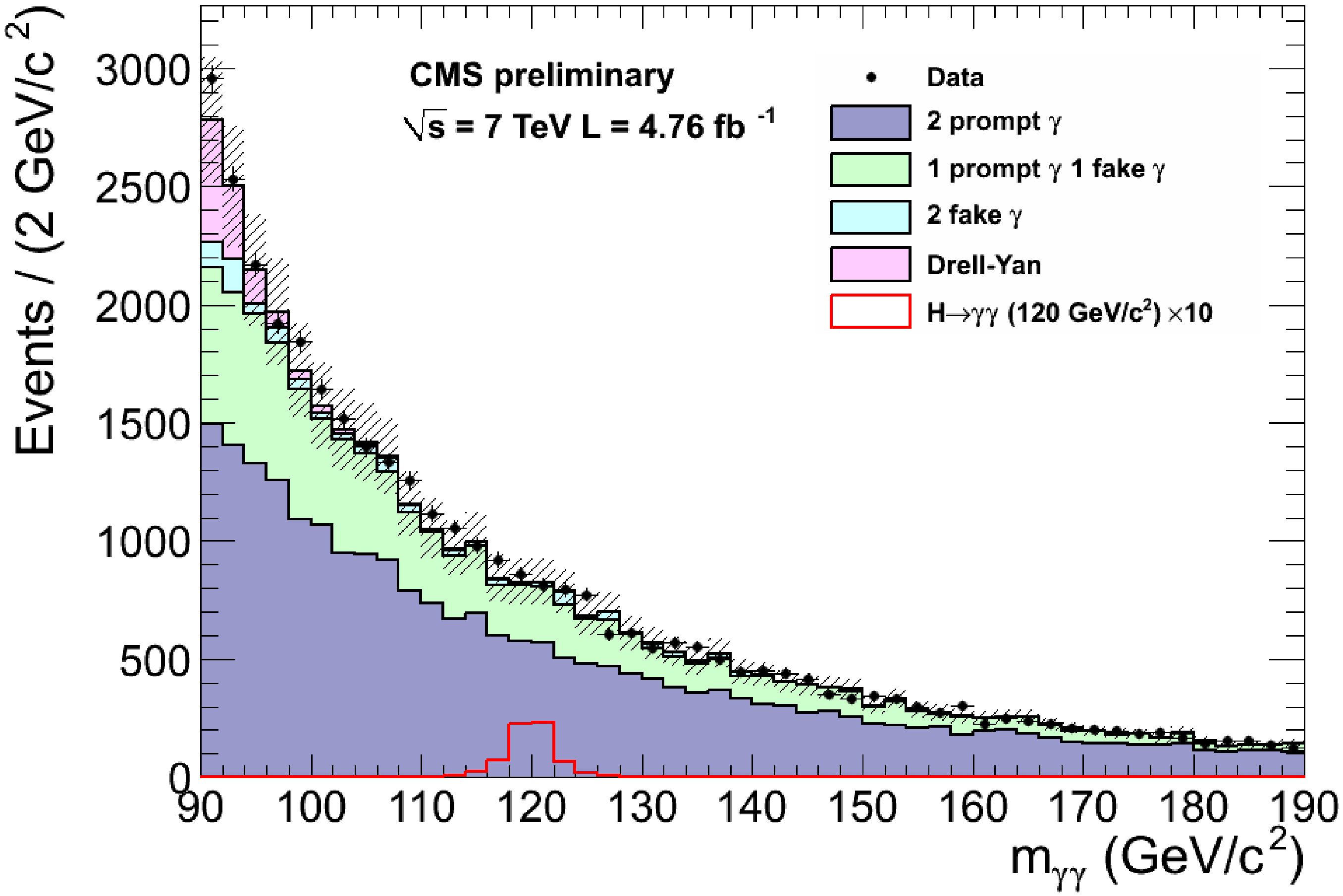
H →2gamma limits



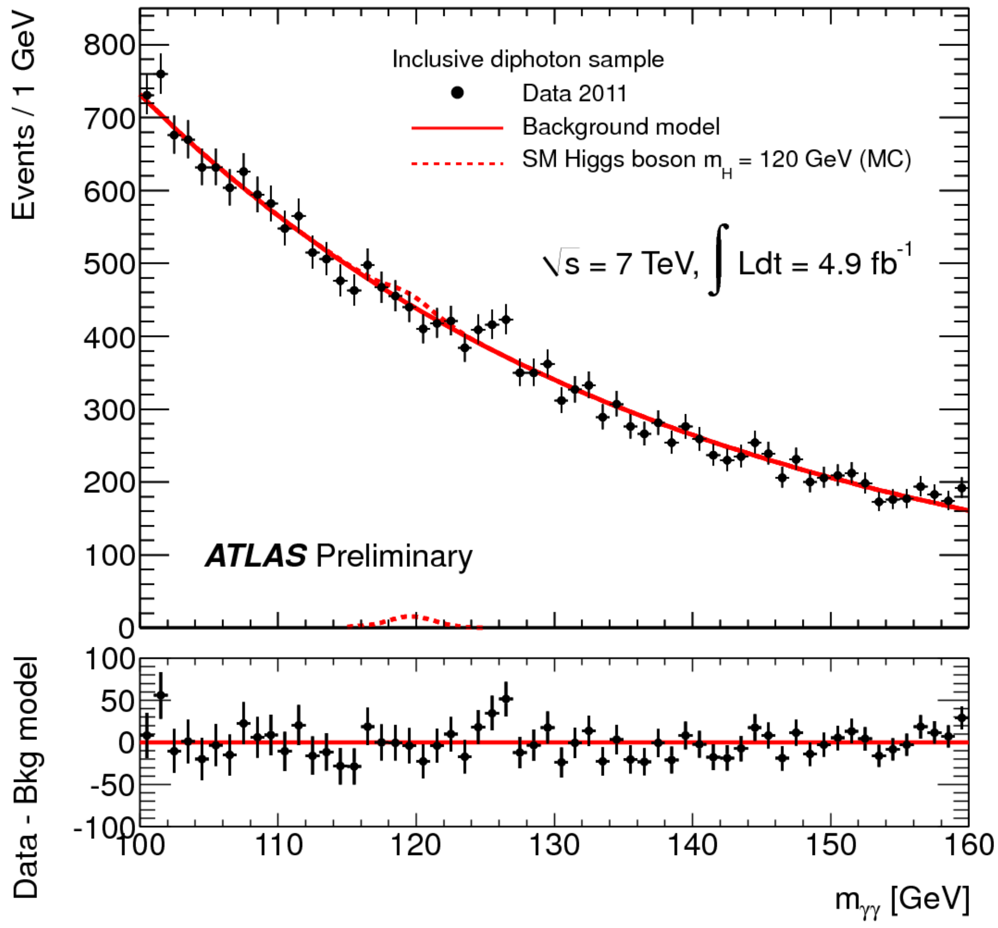
M(2photon) invariant mass distributions



CMS diphoton invariant mass distrbution



ATLAS diphoton mass distribution



Higgs boson combination

- The combination of the SM Higgs boson signatures for L = 4.6 fb^{-1} leads to

Higgs exclusion for mass interval:

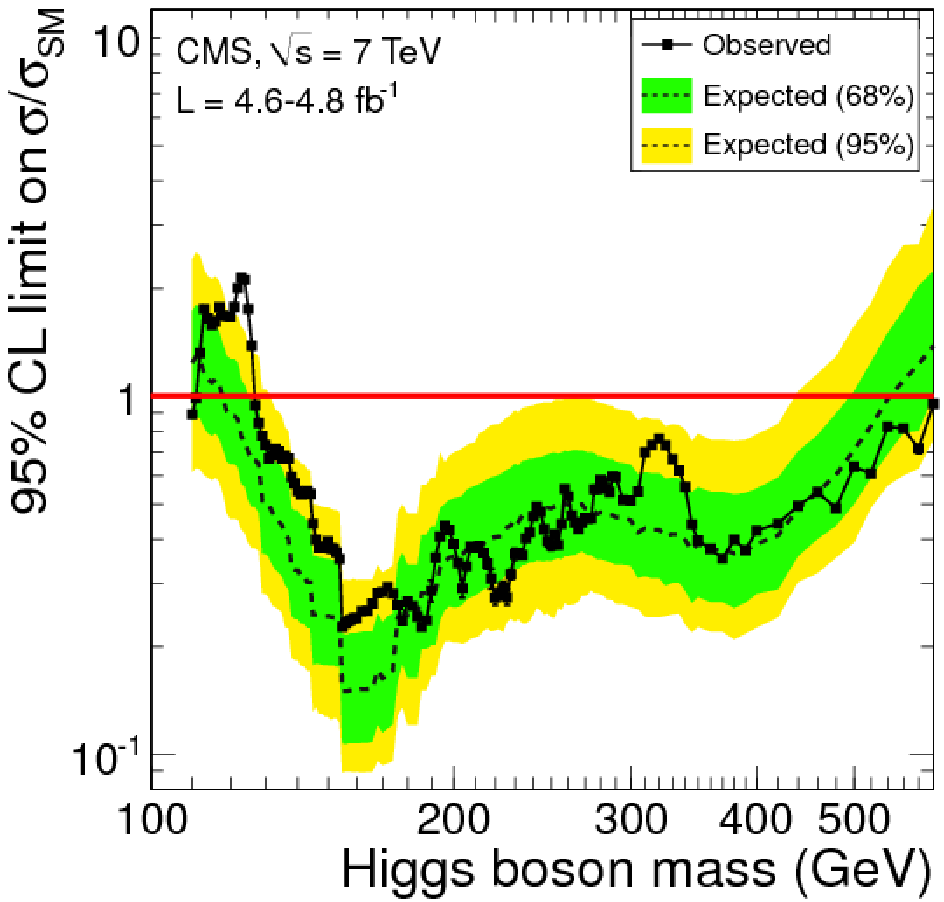
[127, 600] GeV (95% C.L.)

[129, 525] GeV (99% C.L.)

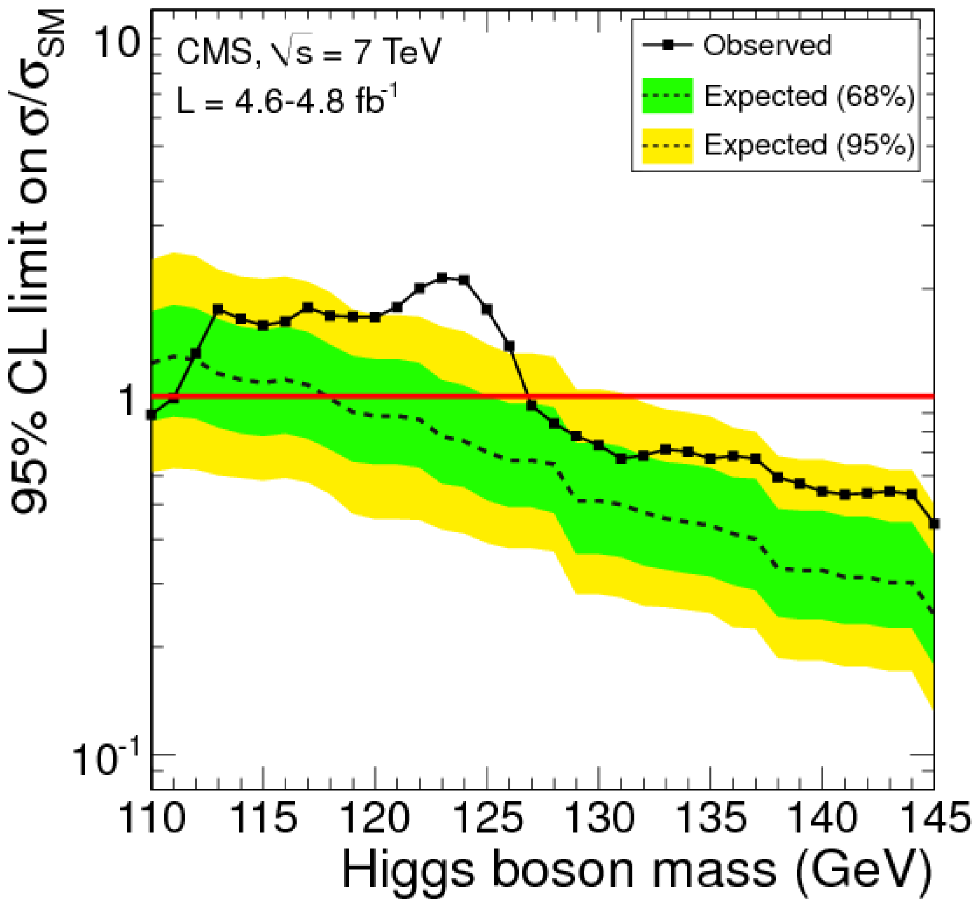
ATLAS(95% C.L.) → [110, 117.5],

[118.5, 122.5], [129, 539] GeV are excluded

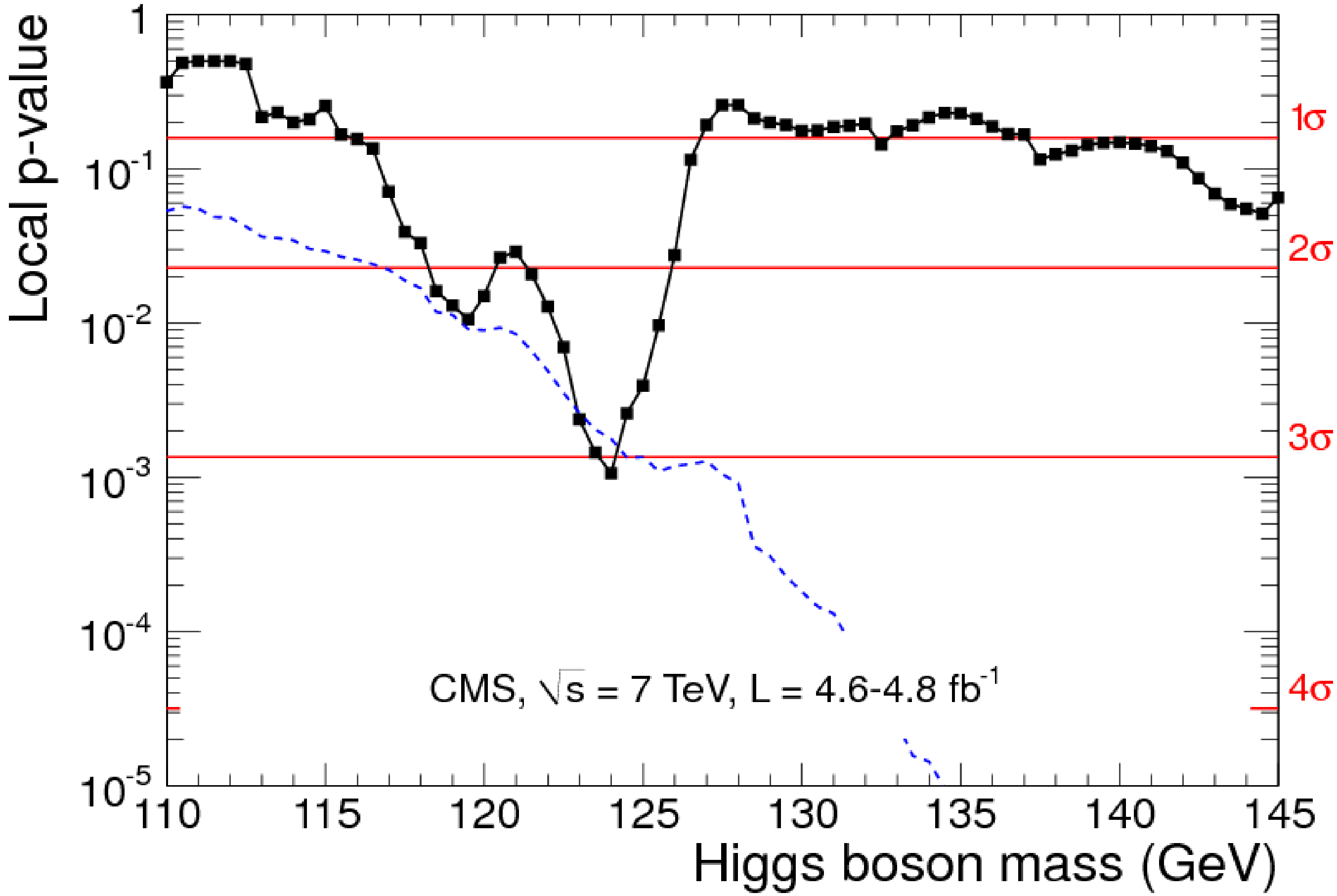
Exclusion region for SM Higgs



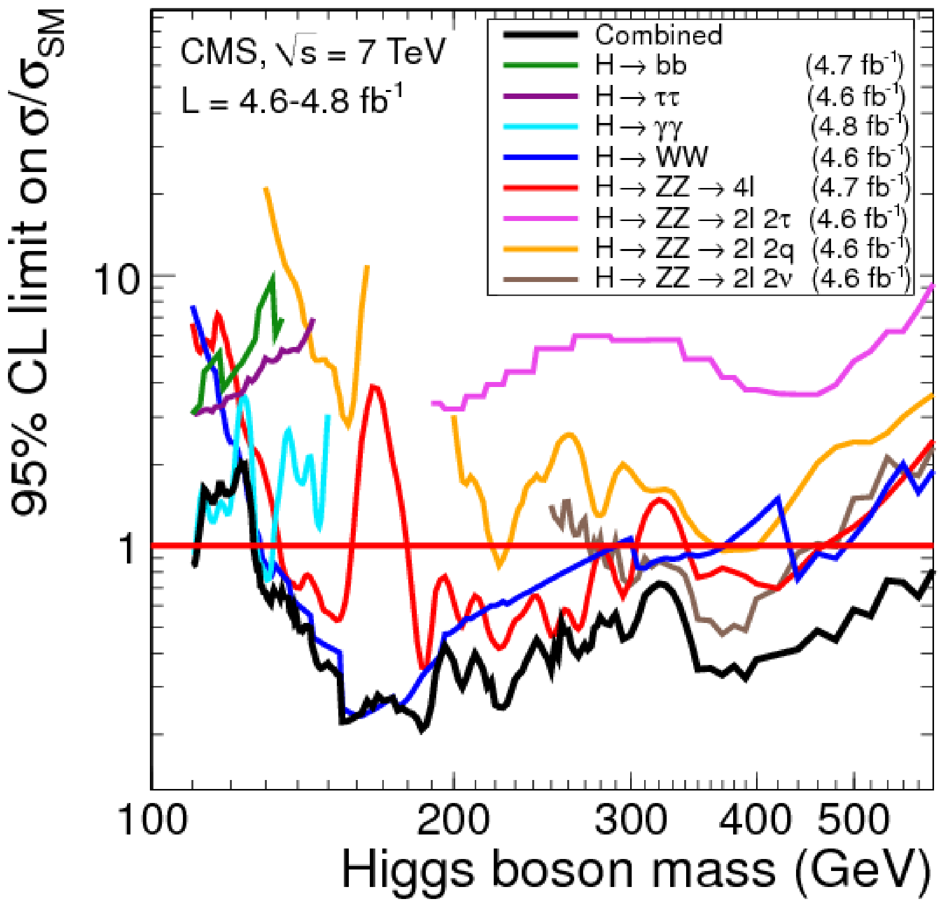
The combined 95% upper limit



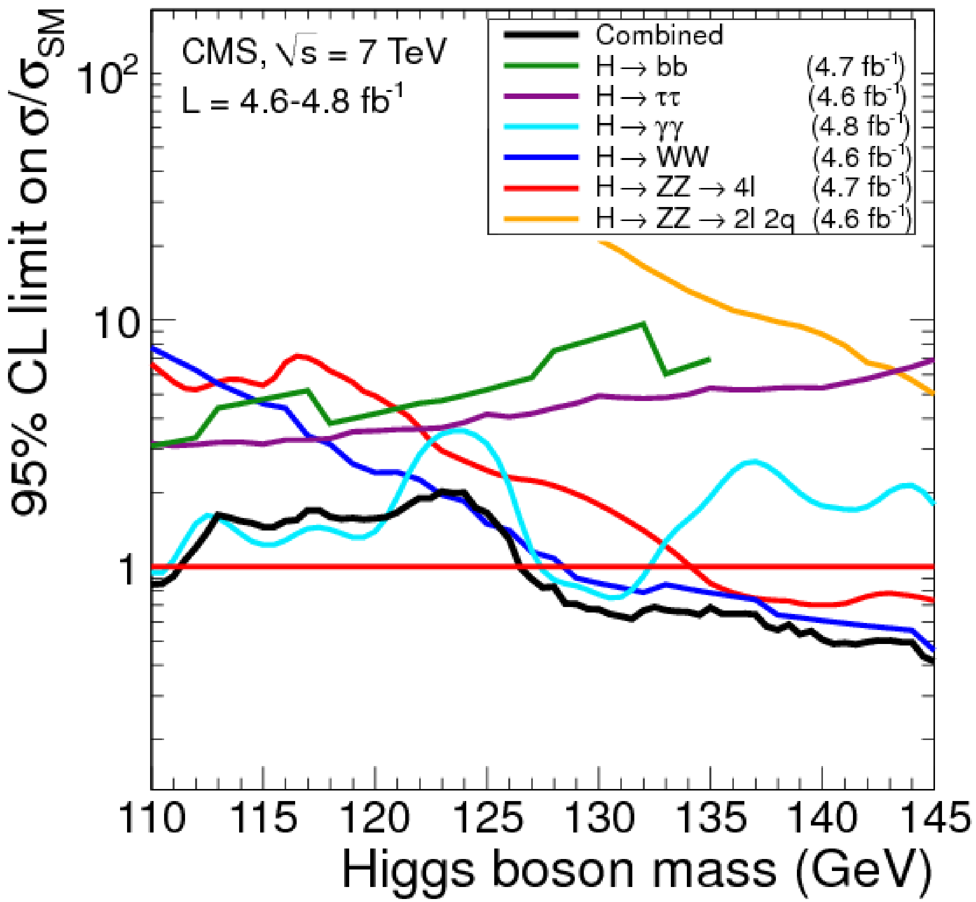
Combined p-values



Individual and combined Higgs boson limits



Individual and combined Higgs boson limits



Higgs boson(Conclusions)

- CMS searched for the Higgs boson in 11 independent channels.
- Expected 95% exclusion M_H in [114.5-543] GeV.
- Observed 95% exclusion M_H in [127.5-600] GeV.
- If the Higgs boson exists, its mass is limited at 95% CL to the range [114.4 – 127.5] GeV.
- An excess around 125 GeV was observed with a local significance of 2.8 σ, corresponding to an global significance of 0.8 σ in the full search range (2.1 σ in the low mass range 110 - 145 GeV).
- The excess is consistent both with a fluctuation of the background and with a SM Higgs boson with a mass around 125 GeV.
- More data is needed to resolve the origin of the excess.

Higgs boson (Conclusions)

The most interesting (discovery) Higgs boson decay modes are:

H → gamma gamma

H → ZZ^*/ZZ → 4l

Weak boson fusion production mechanism is also very promising for Higss boson properties investigation

3. Search for supersymmetry

- Y.A.Goldfarb and E.P.Likhtman
- D.V.Volkov and V.P.Akulov
- J.Wess and B.Zumino
- Why we like SUSY?
- elegant theory
- technical solution of the gauge hierarchy problem
- dark matter → LSP is natural candidate
- consistent string theories are superstring
- theories

SUSY, rules of the game

MSSM – minimal supersymmetric standard model based on $SU_c(3) \otimes SU_L(2) \otimes U(1)$ gauge group. For each known particle → superanalog superparticle (the same mass and internal quantum numbers, difference only in spin)

g (gluon, s = 1) → $\tilde{g}$(gluino , s = ½)

quarks (s = ½) → squarks (s = 0)

leptons (s = ½) → sleptons (s = 0)

gauge bosons (photon, Z- and W-bosons) (s =1) → gaugino (s = ½)

SUSY, rules of the game

H_1, H_2 (two Higgs doublets) (s = 0) → Higgsino (s =1/2)

As a result of gaugino and higgsino mixing

In mass spectrum:

two chargino $\chi_1^{\pm}, \chi_2^{\pm}$ (s = ½)

four neutralino $\chi_1^{0}, \chi_2^{0}, \chi_3^{0}, \chi_4^{0}$ (s = ½)

R-parity conservation postulate → to get rid of dangerous terms leading to fast proton decay.

For ordinary particles R = +1

SUSY, rules of the game

Не удается отобразить рисунок.

For sparticles R = -1

R-parity is conserved by construction

Two important consequences:

1. At supercolliders sparticles are pair produced

2. The lightest sparticle (LSP) is stable: χ_1^0
→ dark matter candidate

- Note that SUSY models with R-parity violation are possible

MSUSGRA model

So SUSY has to be broken and in general masses of sparticles (squarks, sleptons, gluino, gaugino, Higgsino) are arbitrary that makes analysis extremely difficult

For LHC most calculations were done within so called MSUGRA model →

Squark, slepton, higgsino masses are universal at GUT scale → m_0

Gaugino masses also universal→ $m_{1/2}$

Sparticle production

- From cosmology and astrophysics → LSP is weakly interacting neutral particle.
  As a result LSP escapes from detection (analog of neutrino) → SUSY events are characterized by nonzero transverse missing momentum
  In real life SUSY has to be broken

1. gravity mediated SUSY breaking
2. gauge mediated SUSY breaking

Sparticle production

- At LHC sparticles can be produced via reactions:

$$gg, qq, qg \to \tilde{g}\tilde{g}, \tilde{q}\tilde{g}, \tilde{q}\tilde{q}$$

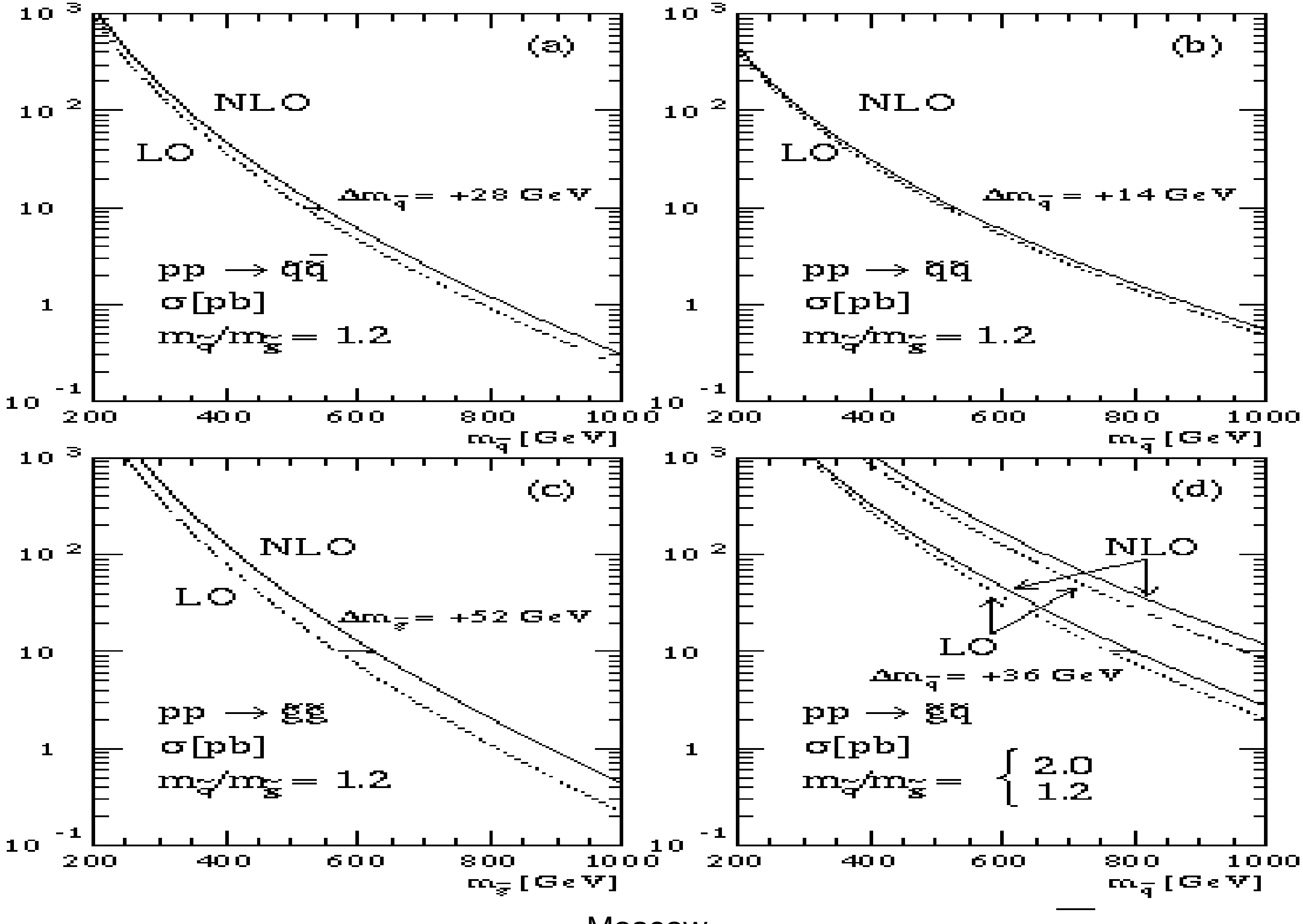
$$qq \to \chi_i^{\pm}\chi_j^{\mp}, \chi_i^{\pm}\chi_j^{0}, \chi_i^{0}\chi_j^{0}$$

$$qq, qg \to \tilde{g}\chi_i^{0}, \tilde{g}\chi_i^{\pm}, \tilde{q}\chi_i^{0}, \tilde{q}\chi_i^{\pm}$$

$$qq \to \tilde{l}\tilde{\nu}, \tilde{l}\tilde{l}, \tilde{\nu}\tilde{\nu}$$

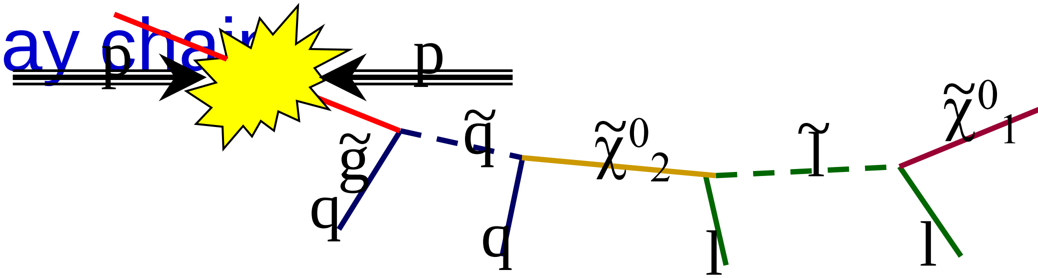
For squarks and gluino with masses O(1) TeV
squark and gluino cross sections O(1) pb

The total SUSY cross sections



LHC SUSY Searches

Typical Signature/decay chain



- Strongly interacting sparticles (squarks, gluinos) dominate production.
- Heavier than sleptons, gauginos etc. g cascade decays to LSP.
- Potentially long decay chains and large mass differences
  - **Many high p_T objects observed (leptons, jets, b-jets).**
- If R-Parity conserved LSP (lightest neutralĩno in mSUGRA) stable and sparticles pair produced.
  - **Large E_T^{miss} signature (c.f. Wglν).**

SUSY Searches

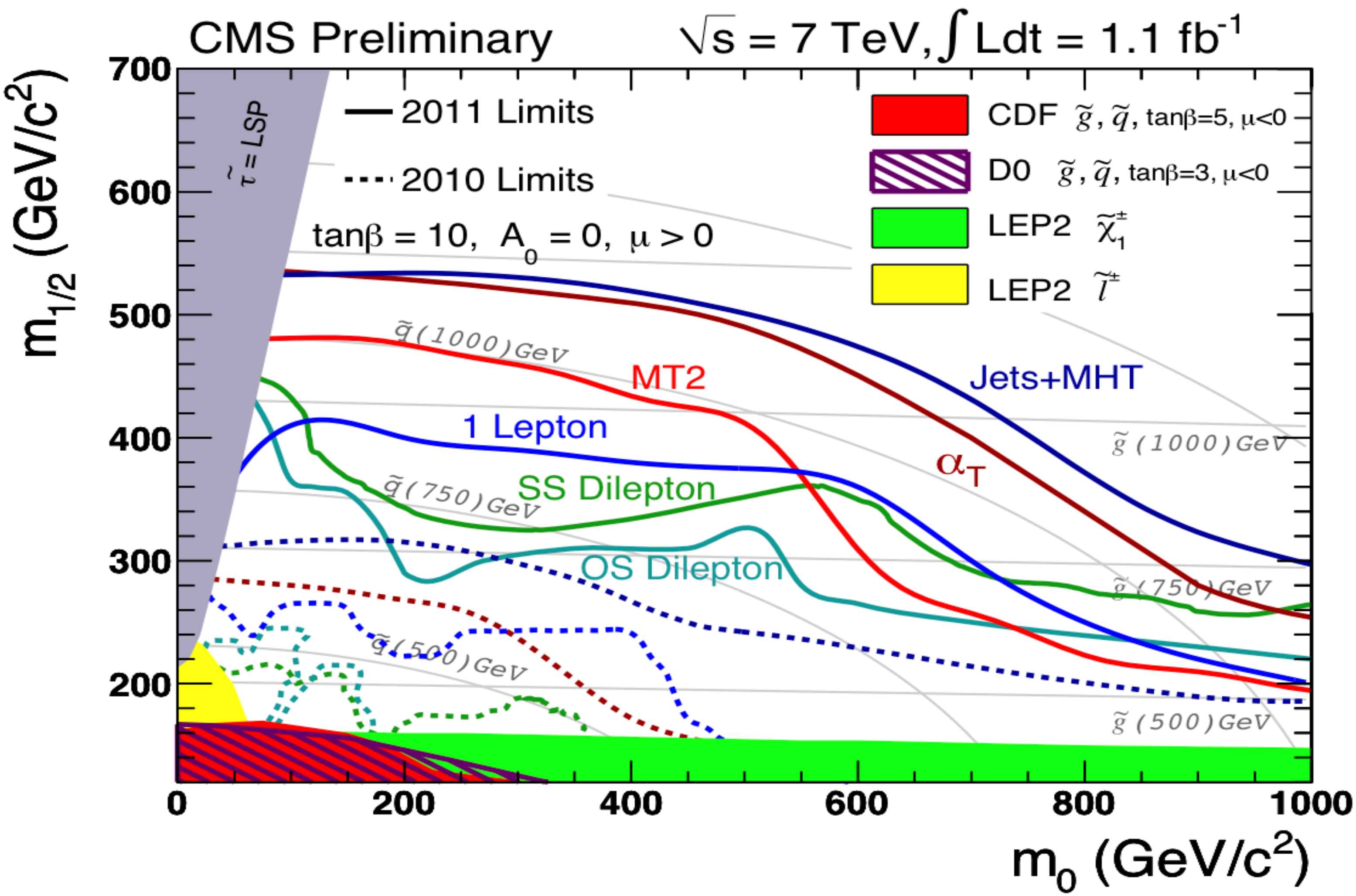
- Inclusive searches to detect SUSY with first data
- Exclusive studies – performed with more data to determine model parameters e.g. masses etc from end point measurements…

Susy signatures

As a result of squark, gluino decays and chargino and neutralino decays the most interesting signatures for the search for SUSY at LHC are:

- multijets plus E_T^{miss} events
- 1l plus jets plus E_T^{miss} events
- 2l plus jets plus E_T^{miss} events
- 3l plus jets plus E_T^{miss} events
- 4l plus jets plus E_T^{miss} events

CMS SUSY bounds for MSUGRA



The use of razor variables

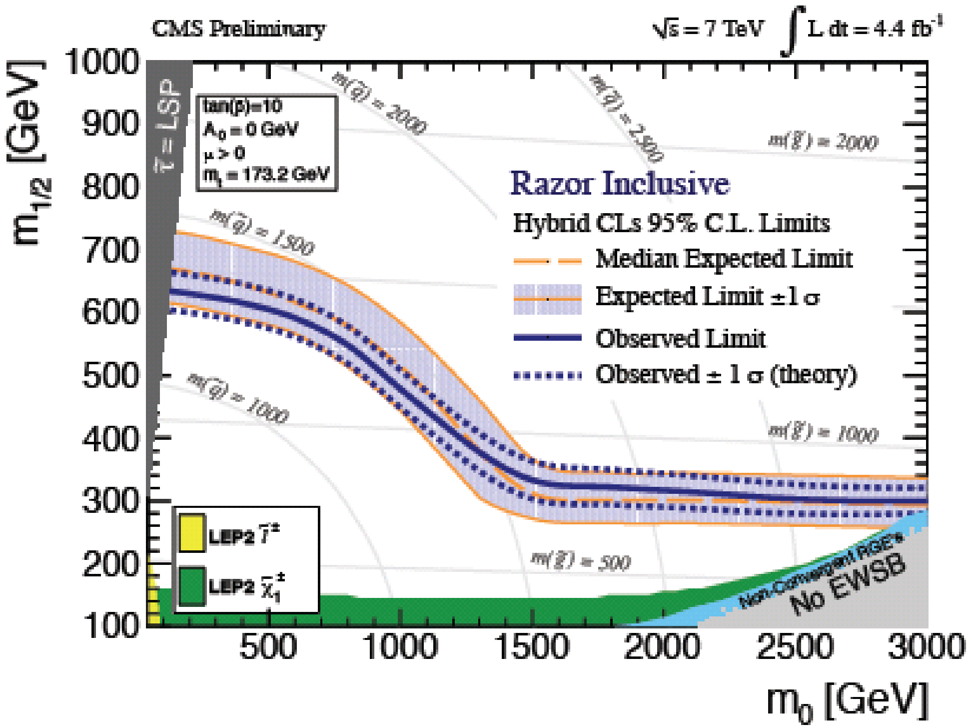
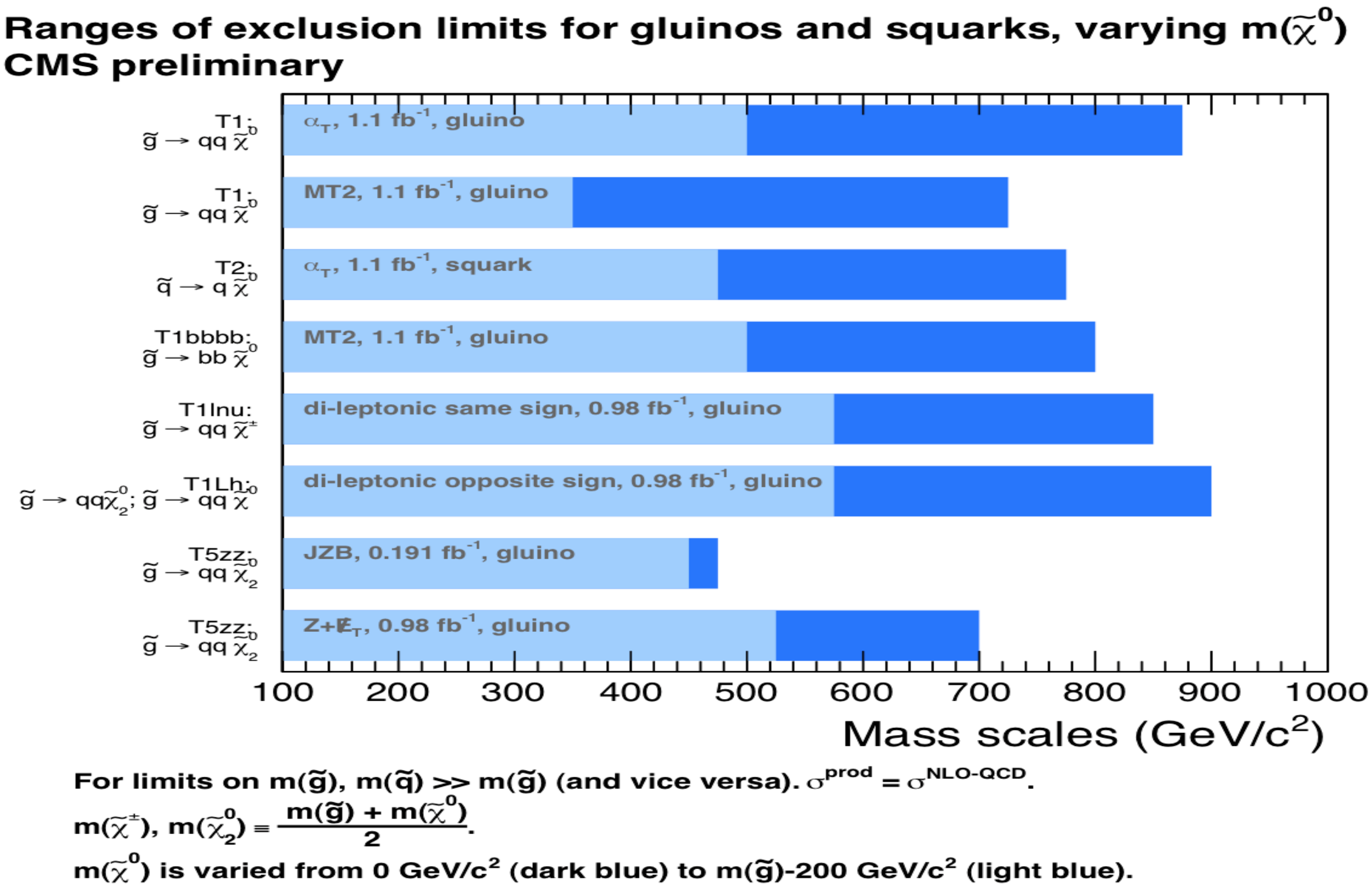


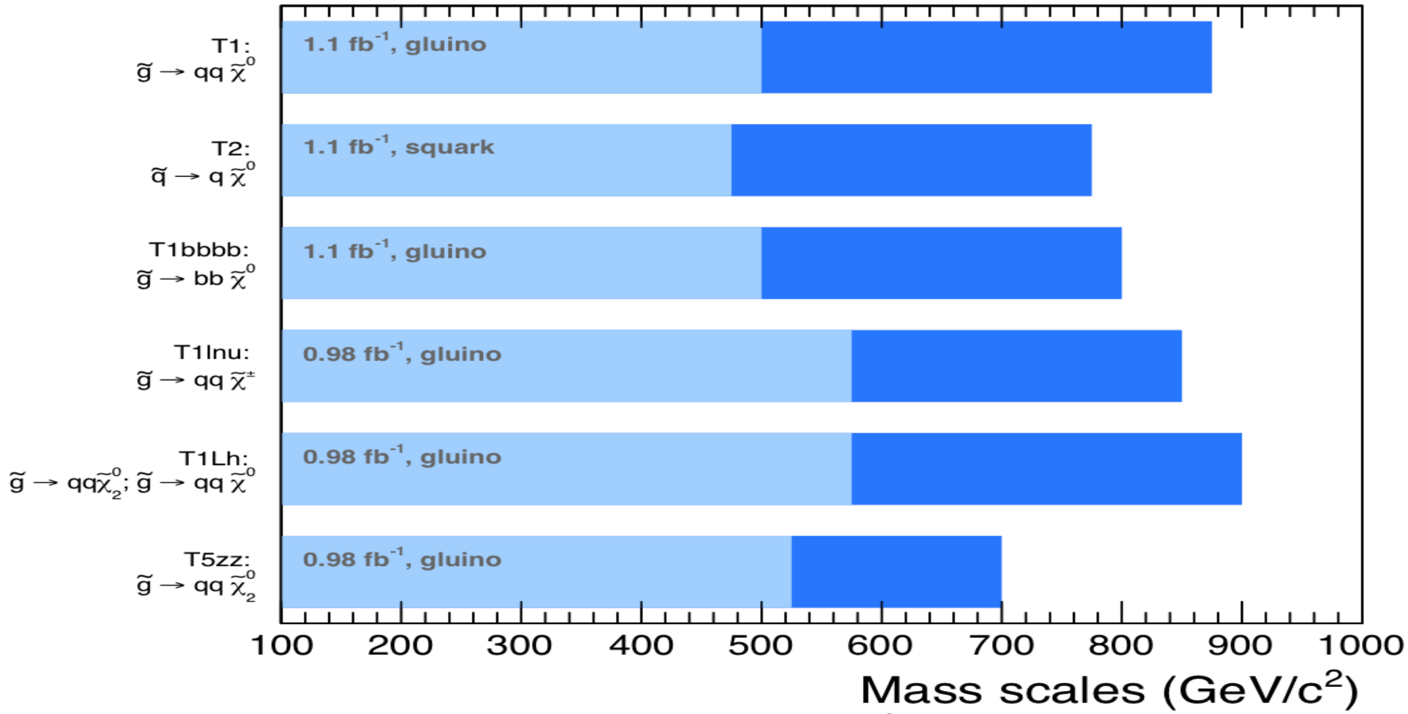
Figure 10: Observed (solid curve) and median expected (dot-dashed curve) 95% CL limits in the $(m_0, m_{1/2})$ CMSSM plane with $\tan\beta = 10$, $A_0 = 0$, $\mathrm{sgn}(\mu) = +1$ from the razor analysis. The $\pm$ one standard deviation equivalent variations in the uncertainties are shown as a band around the median expected limit.

Exclusion limits for squrk and gluino



Exclusion limits for squarks and gluino

Ranges of exclusion limits for gluinos and squarks, varying $m(\tilde{\chi}^0)$
CMS preliminary

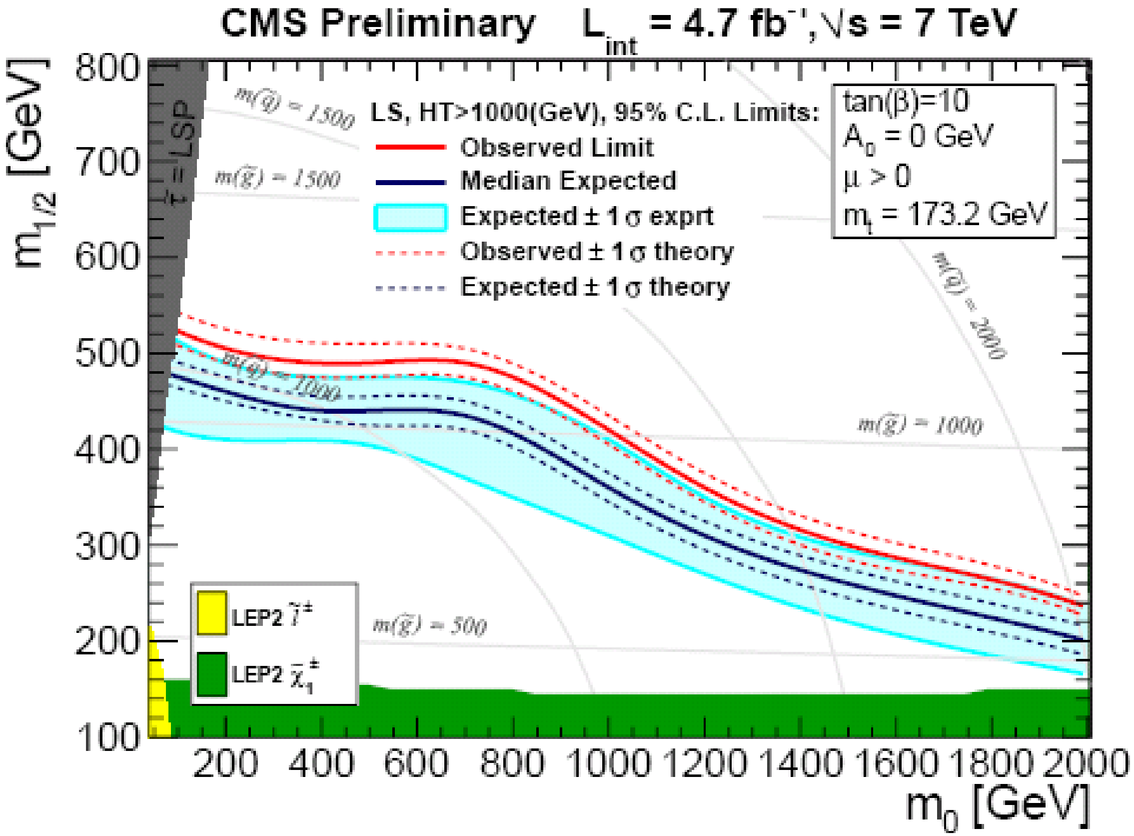


For limits on $m(\tilde{g})$, $m(\tilde{q}) >> m(\tilde{g})$ (and vice versa). $\sigma^{prod} = \sigma^{NLO\text{-}QCD}$.

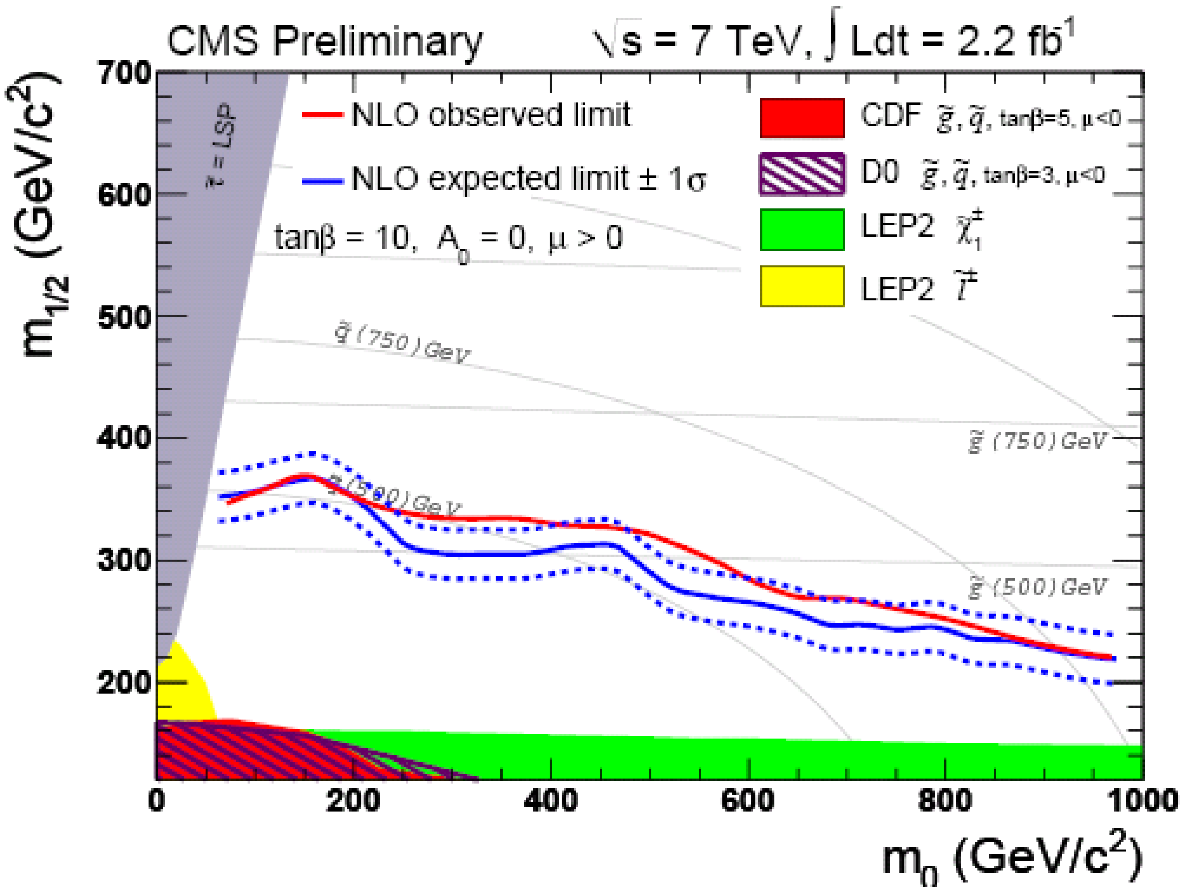
$$m(\tilde{\chi}^\pm),\ m(\tilde{\chi}_2^0) \equiv \frac{m(\tilde{g}) + m(\tilde{\chi}^0)}{2}.$$

$m(\tilde{\chi}^0)$ is varied from 0 GeV/c^2 (dark blue) to $m(\tilde{g})$-200 GeV/c^2 (light blue).

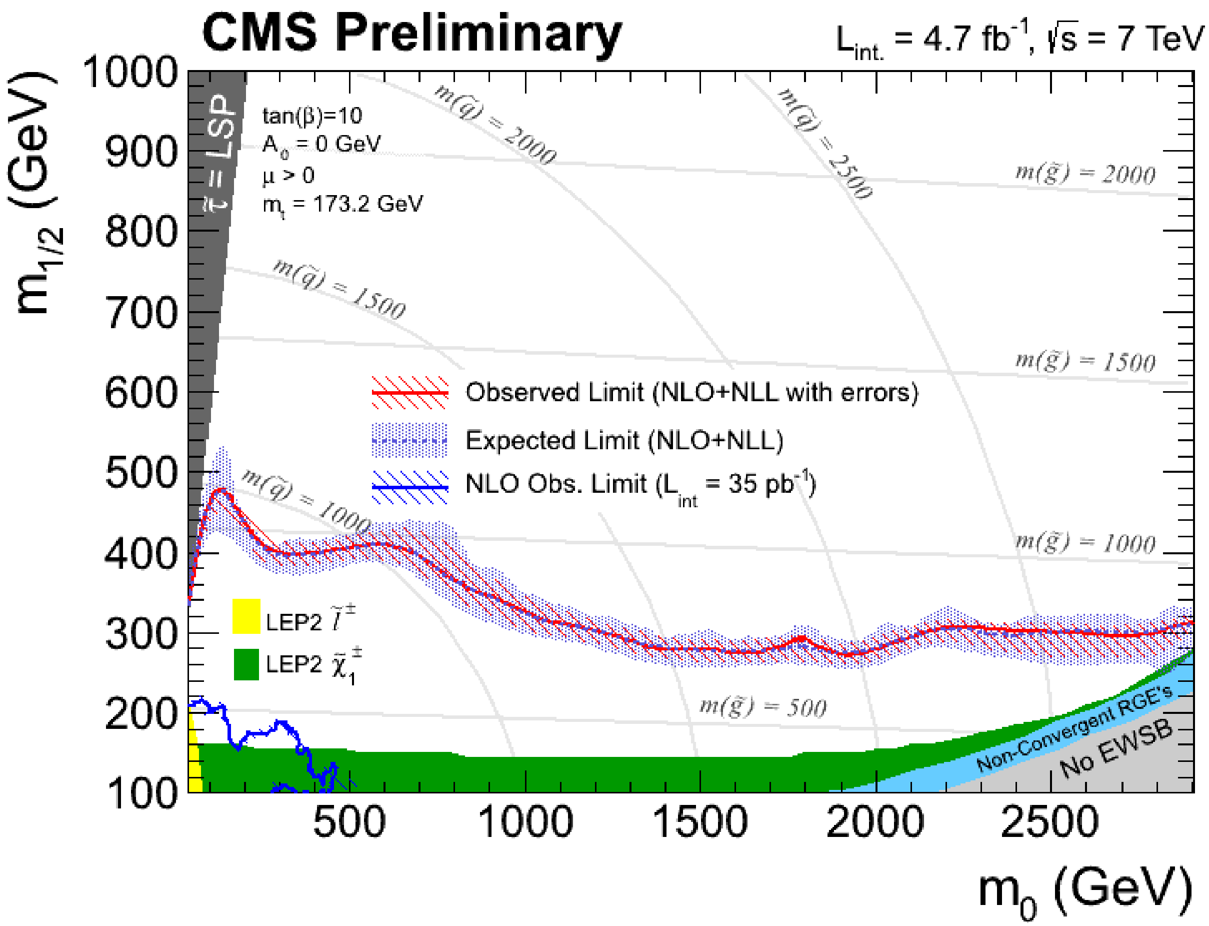
Single lepton bounds



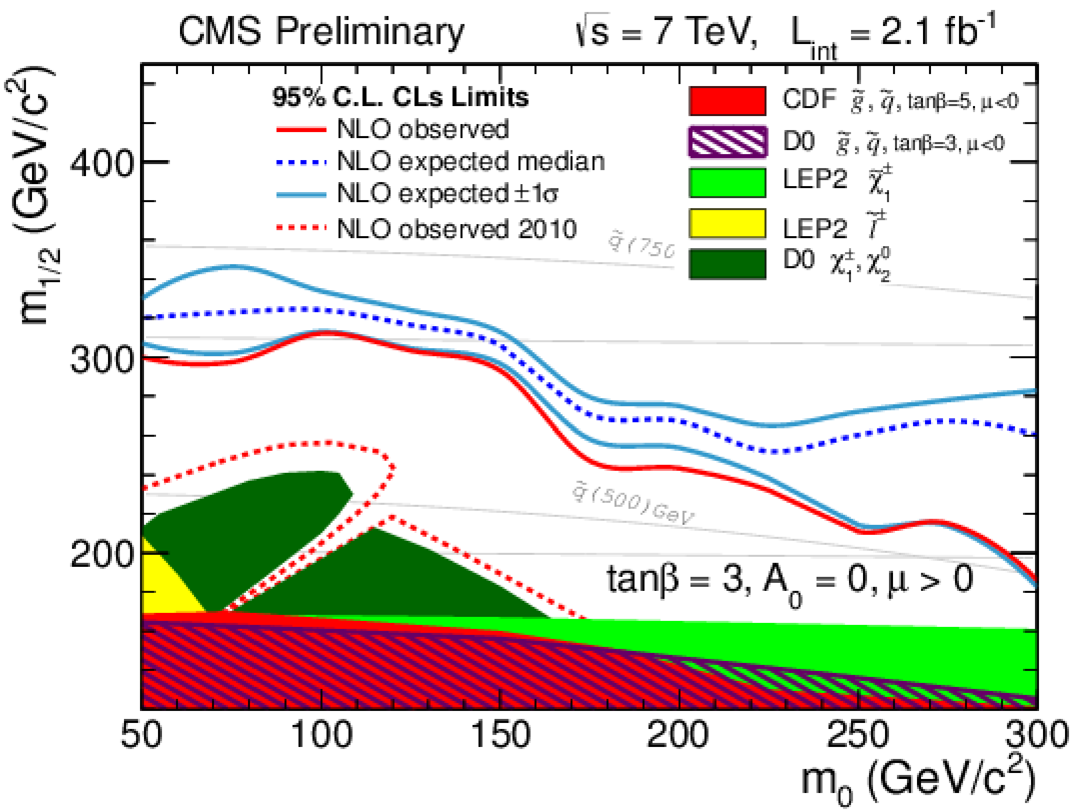
Opposite-sign dileptons bounds



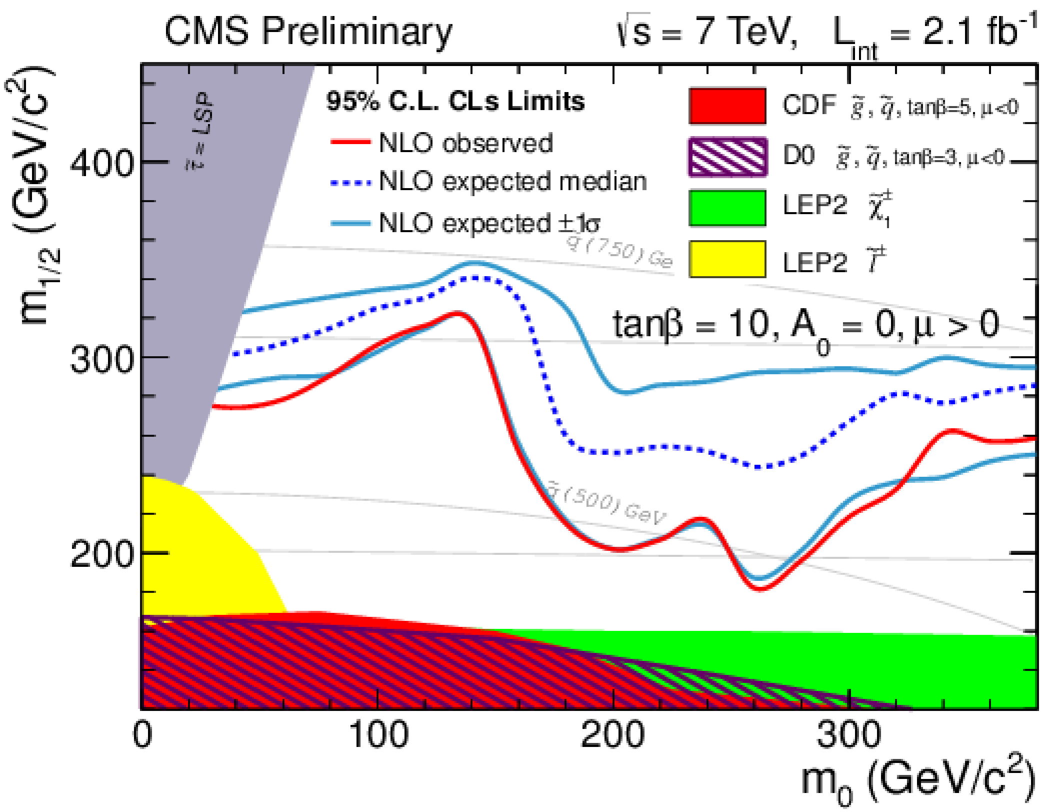
Same-sigh dileptons



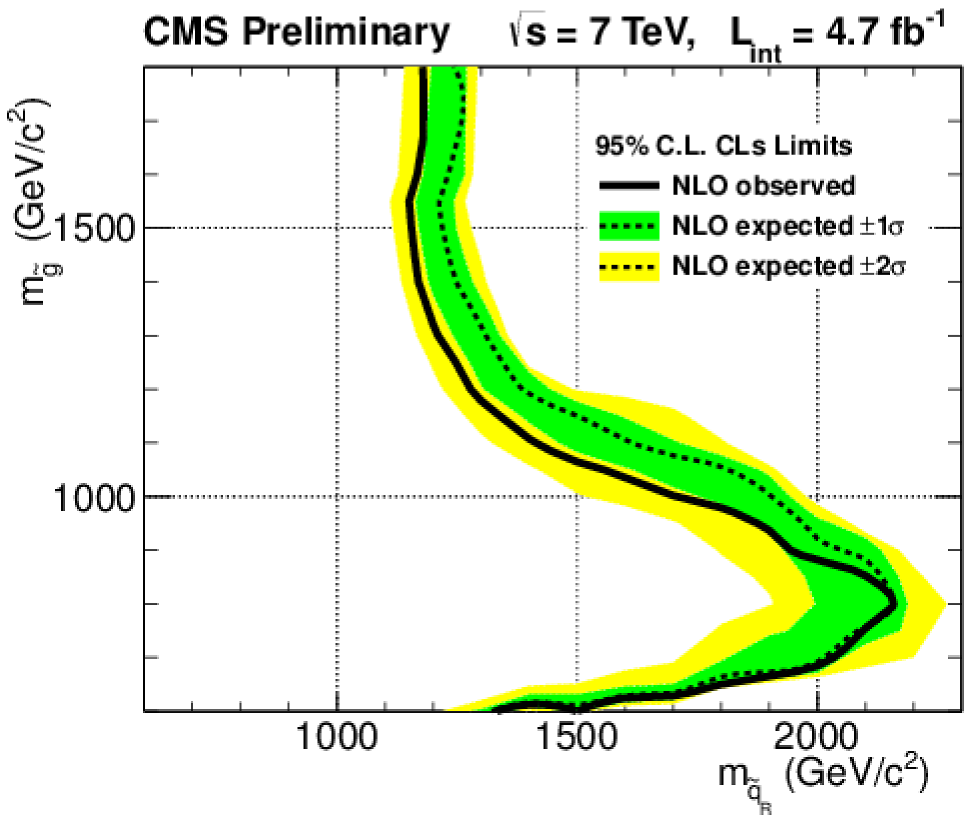
3 leptons +E^T_miss signature



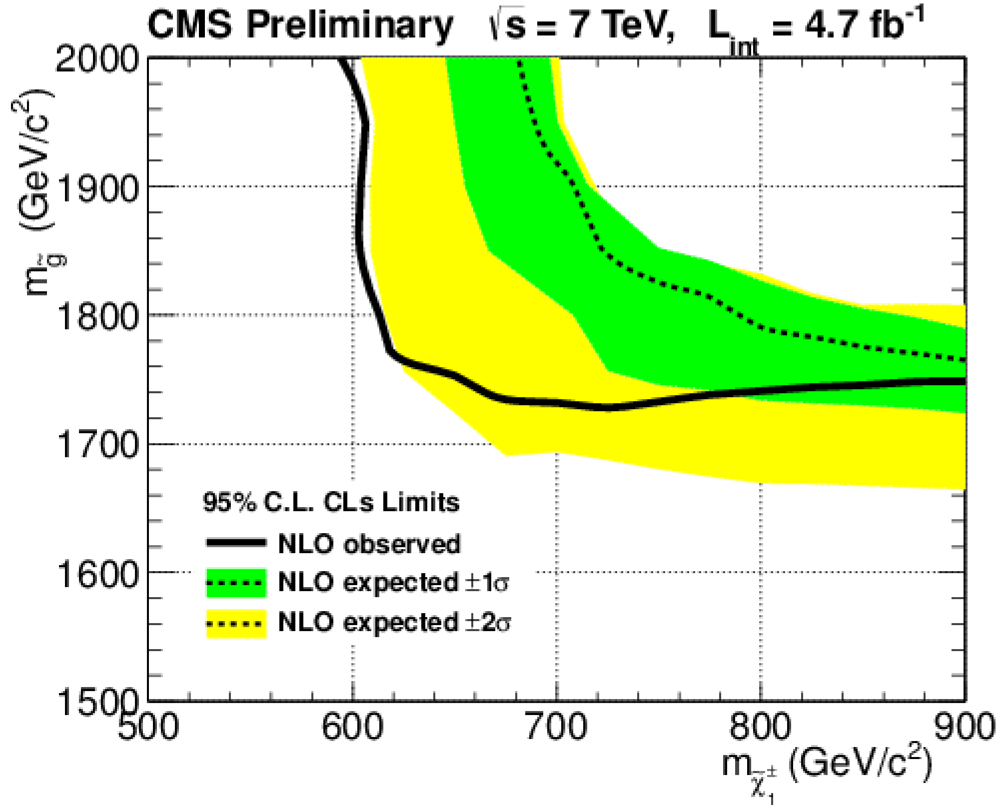
3 leptons +E^T_miss signature



Multilepton bound



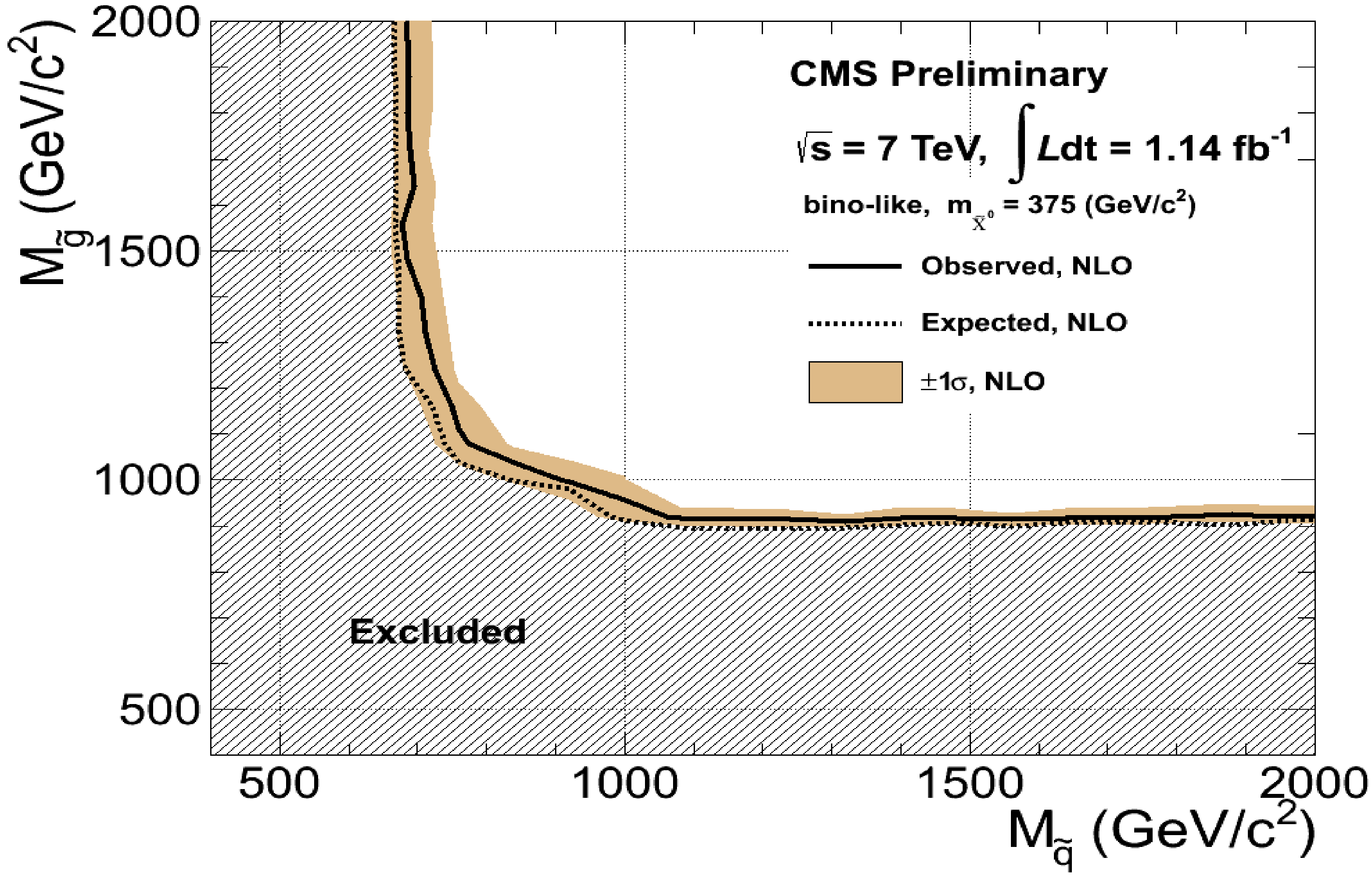
Multilepton bound



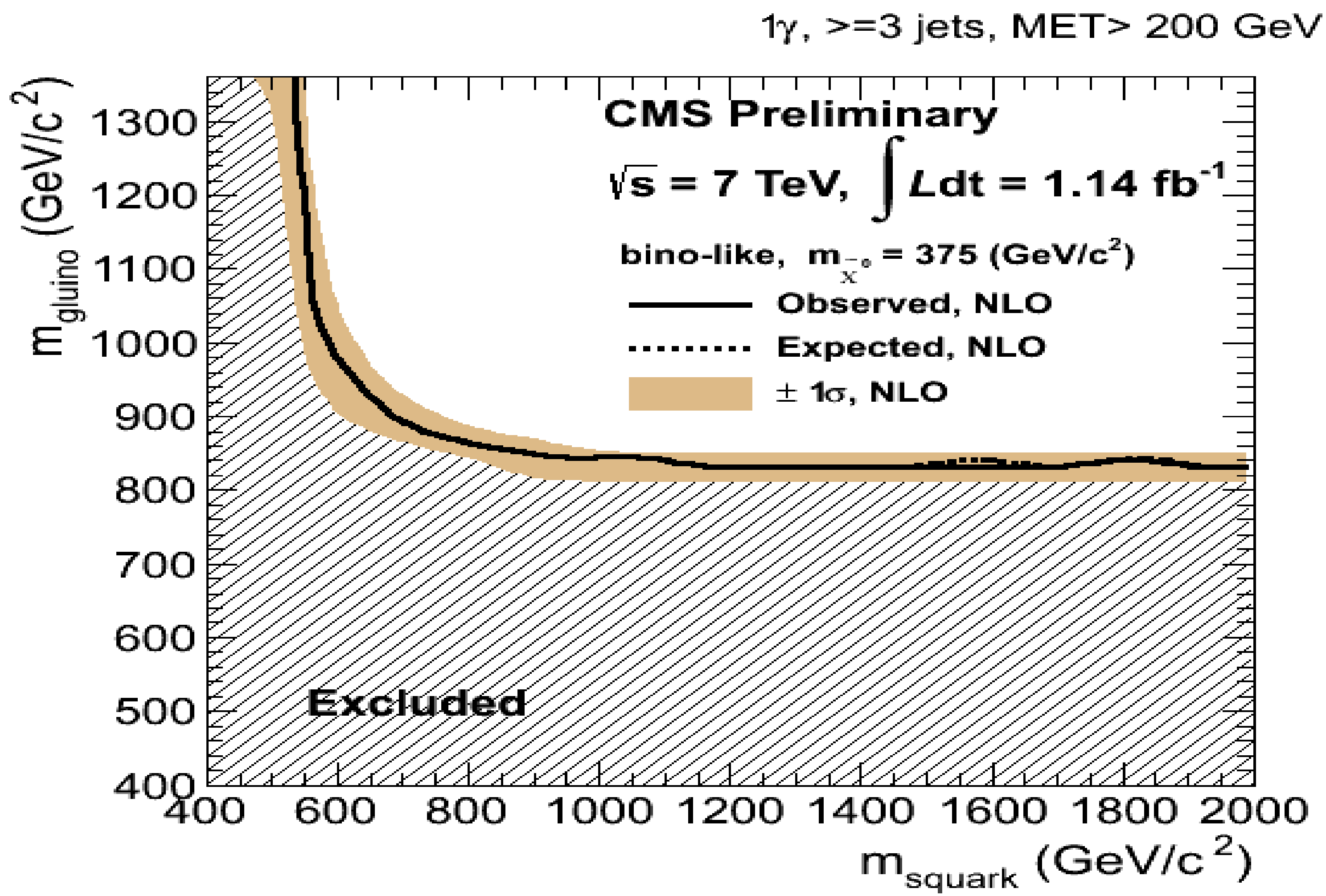
Search for gauge mediated SUSY

- LSP decays (within detector) into photon and gravitino
- Signature:
- Jets + E^T-miss + >1 photons

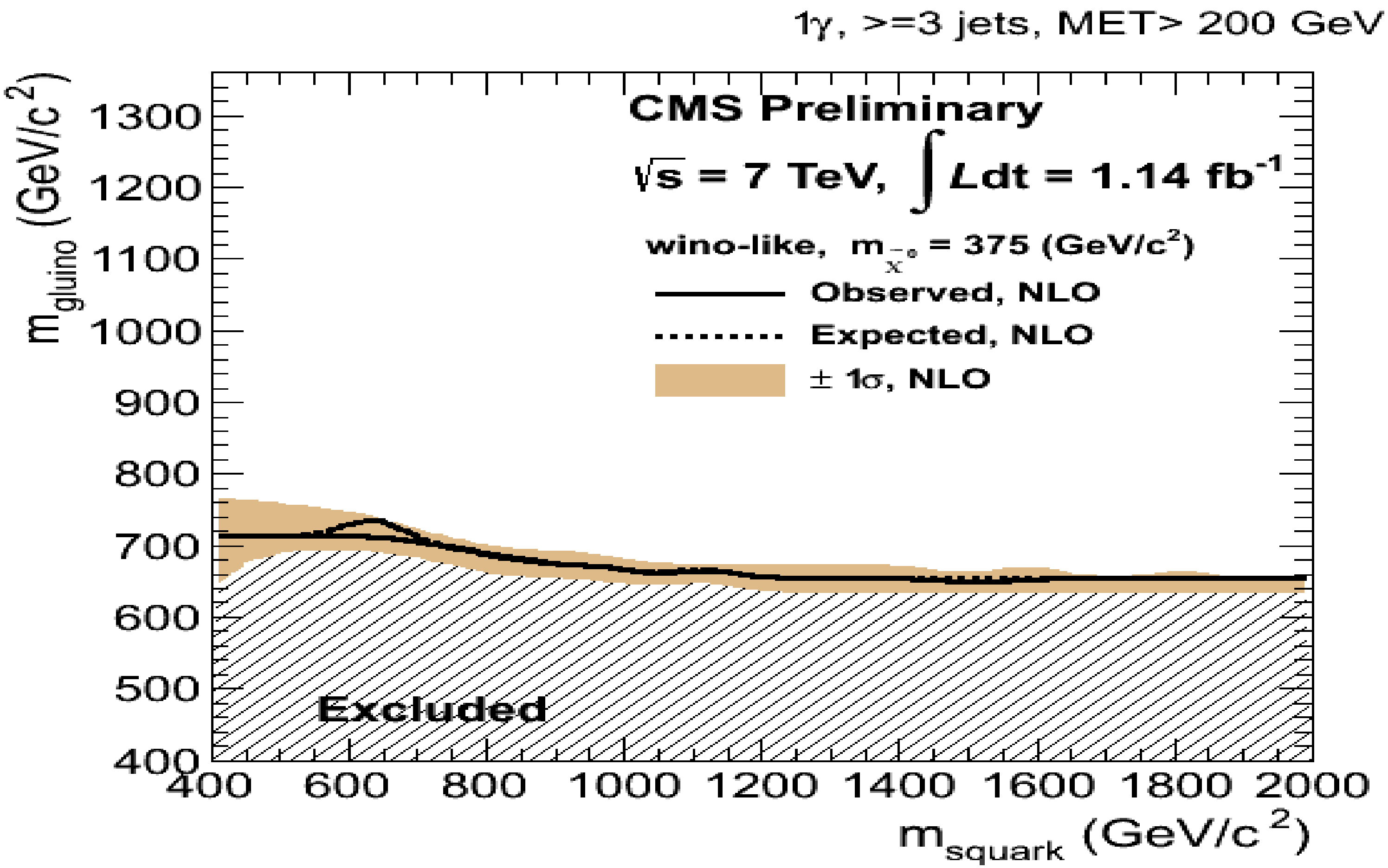
Search for gauge mediated SUSY



Search for gauge mediated SUSY



Search for gauge mediated SUSY



At present: No SUSY at LHC

- Can we forget it?

At present: No SUSY at LHC

- То, о чем писал поэт – это бред?

  В. Высоцкий

Как много красивых теорий уродуют ужасные факты

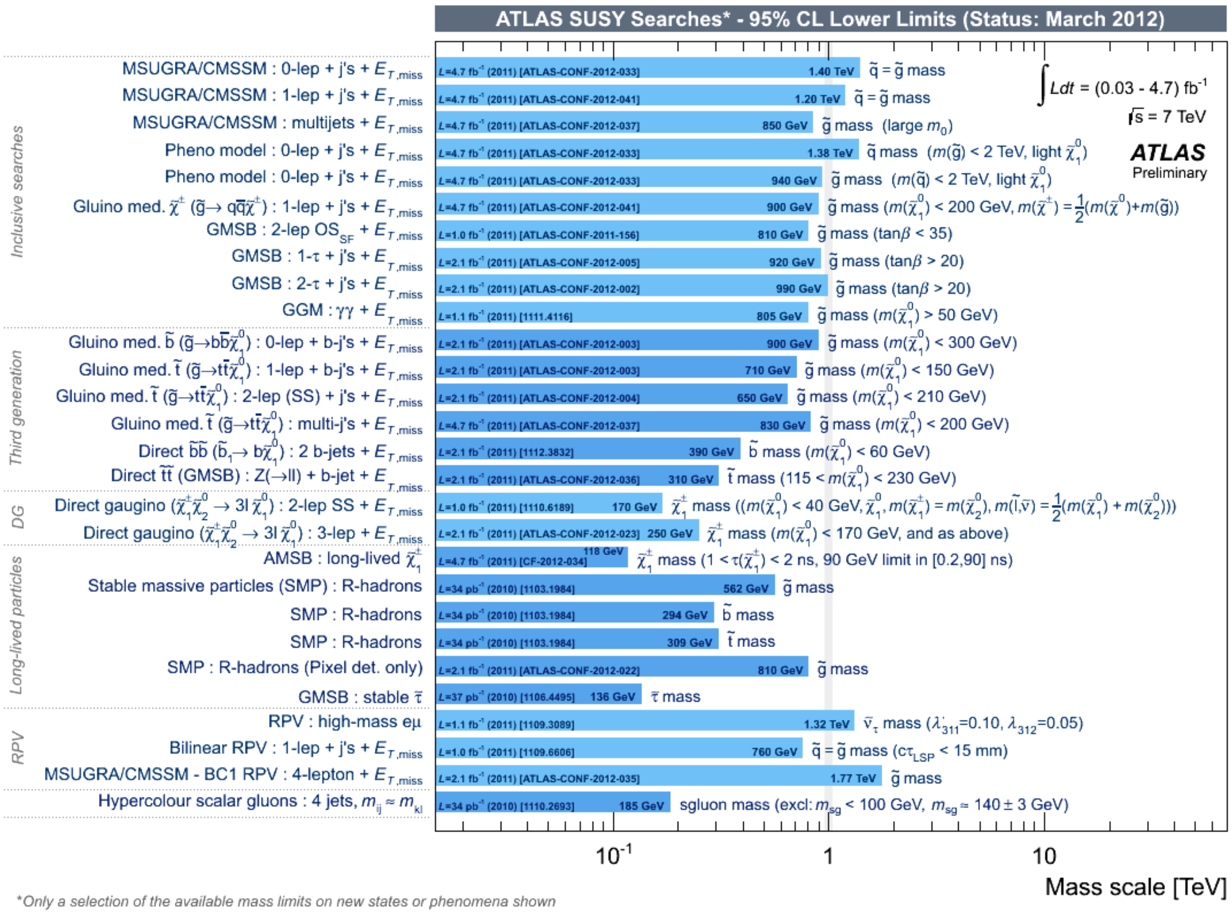
At present: No SUSY at LHC

Or:

Let us wait and see?

Your opinion?

SUSY mass reach of ATLAS



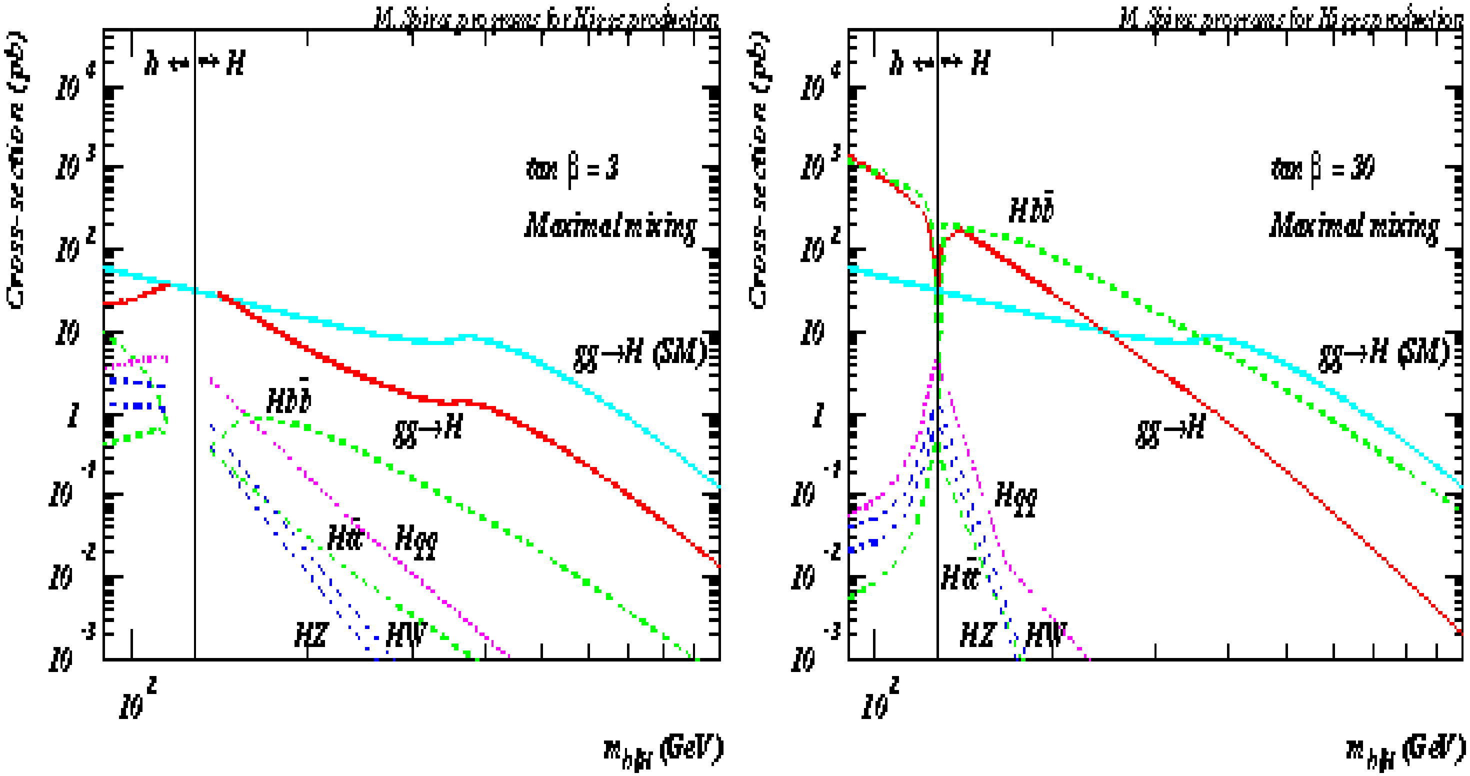
MSSM Higgs boson searches

- In the MSSM there are 4 Higgs bosons $h, H, A, H^{+/-}$ the lightest scalar h for $m_A > m_h^{max}$ (decoupling regime) is SM-like Higgs boson.

  The production of H and A proceeds mainly through $gg \rightarrow H/A$ and $gg/qq \rightarrow bbH/A$

- At large tan(beta) bbH/A production dominates and it is ~90% for tan(beta) >10 and $m_A > 300$ GeV

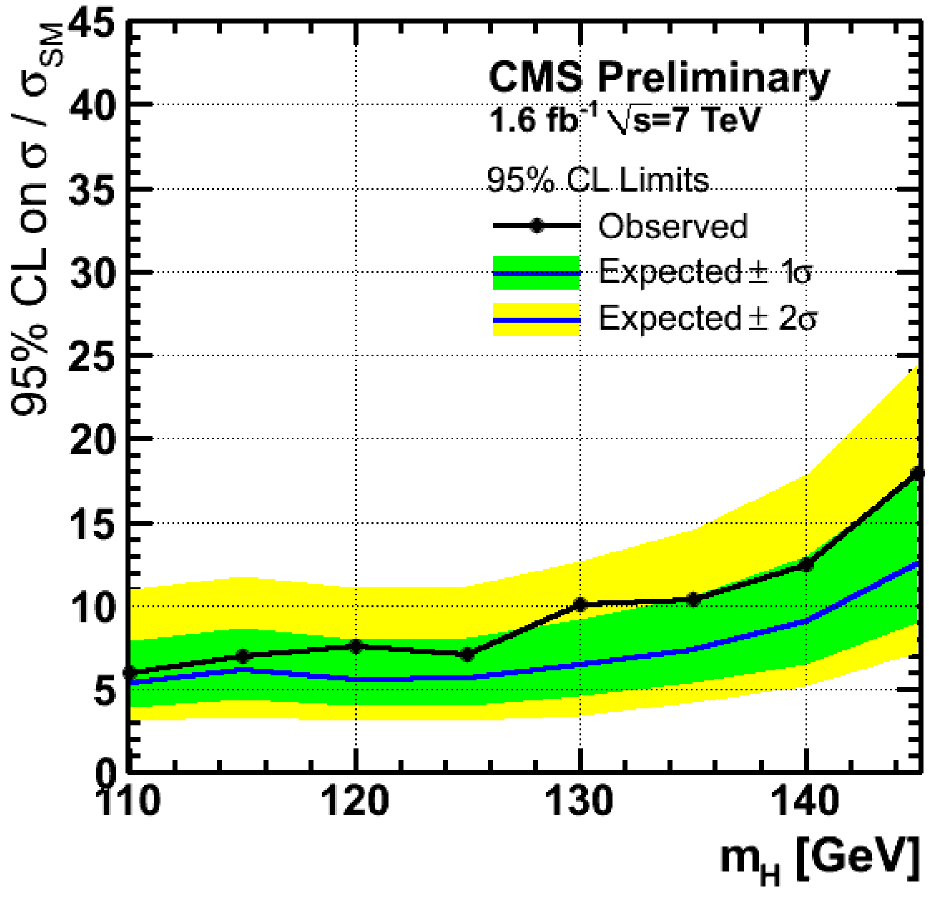
The cross sections of light h and heavy H as a function of their masses



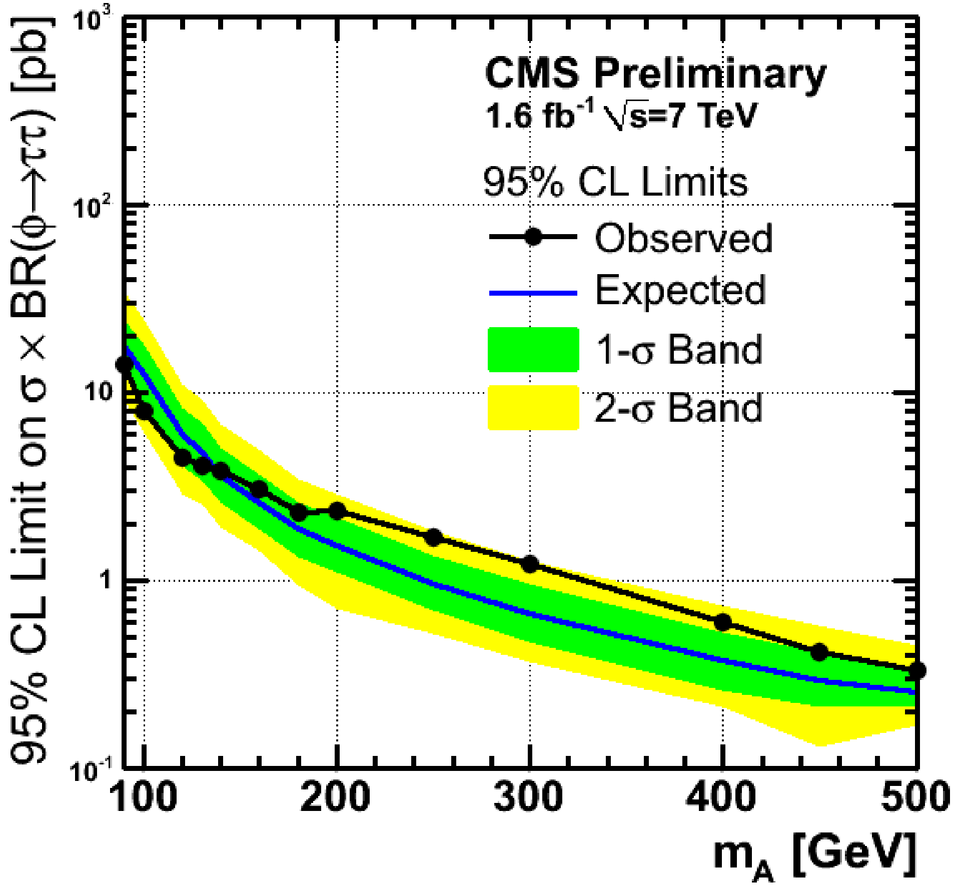
The MSSM Higgs boson signatures

- Light charged Higgs boson $m_{H+/} < m_{top}$ is produced in tt events with $t \rightarrow H^{+/} b$
- The most important production mechanisms for $m_{H+/} > m_{top}$ are
  $gb \rightarrow tH^{+}$, $gg \rightarrow tbH^{+/}$, $qqbar \rightarrow H^{+/}$
  with cross sections ~$\tan^2$(beta)
- The H,A $\rightarrow$b,bbar decay dominates at large tan(beta). The branching to $\tau^+\tau^-$ is ~10% and to $\mu^+\mu^-$ is about $3*10^{-4}$

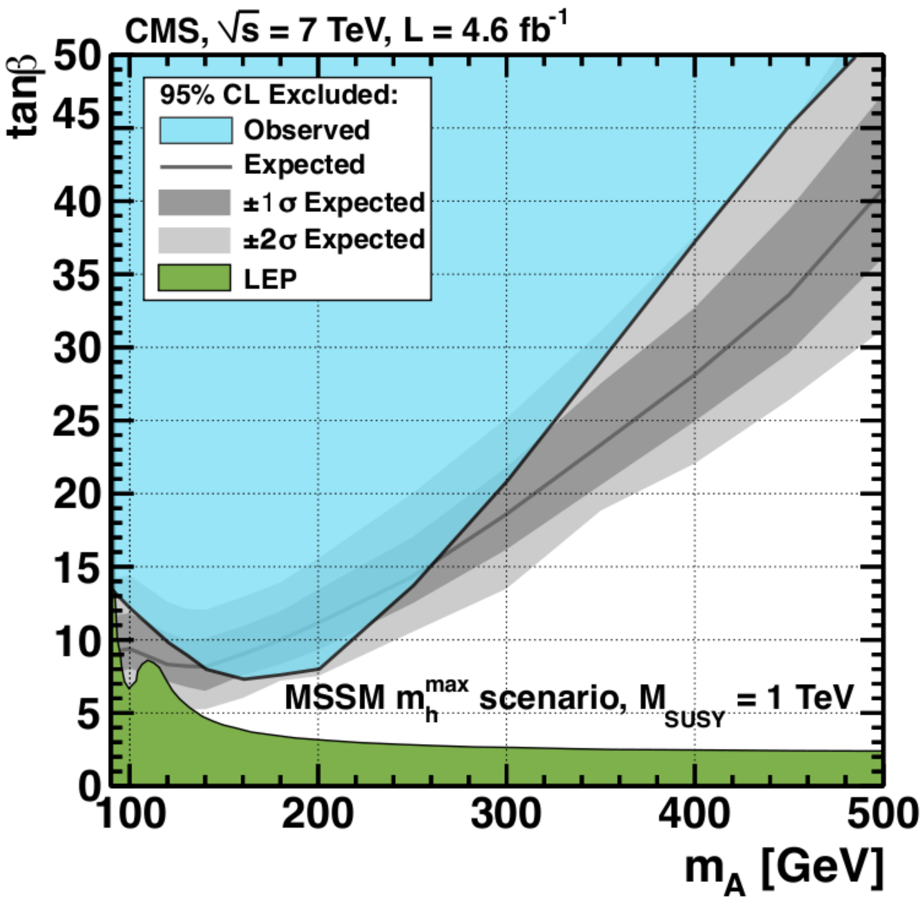
H→tau tau signature



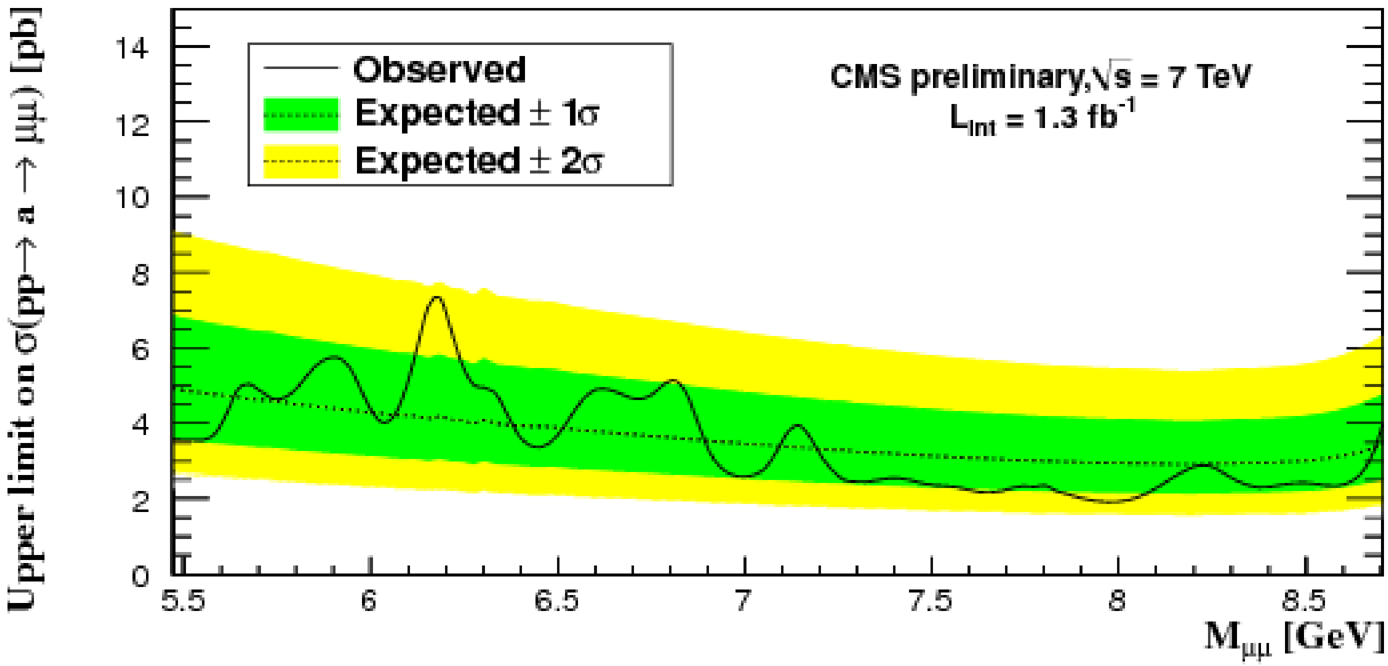
H→tau tau signature



MSSM Higgs bound

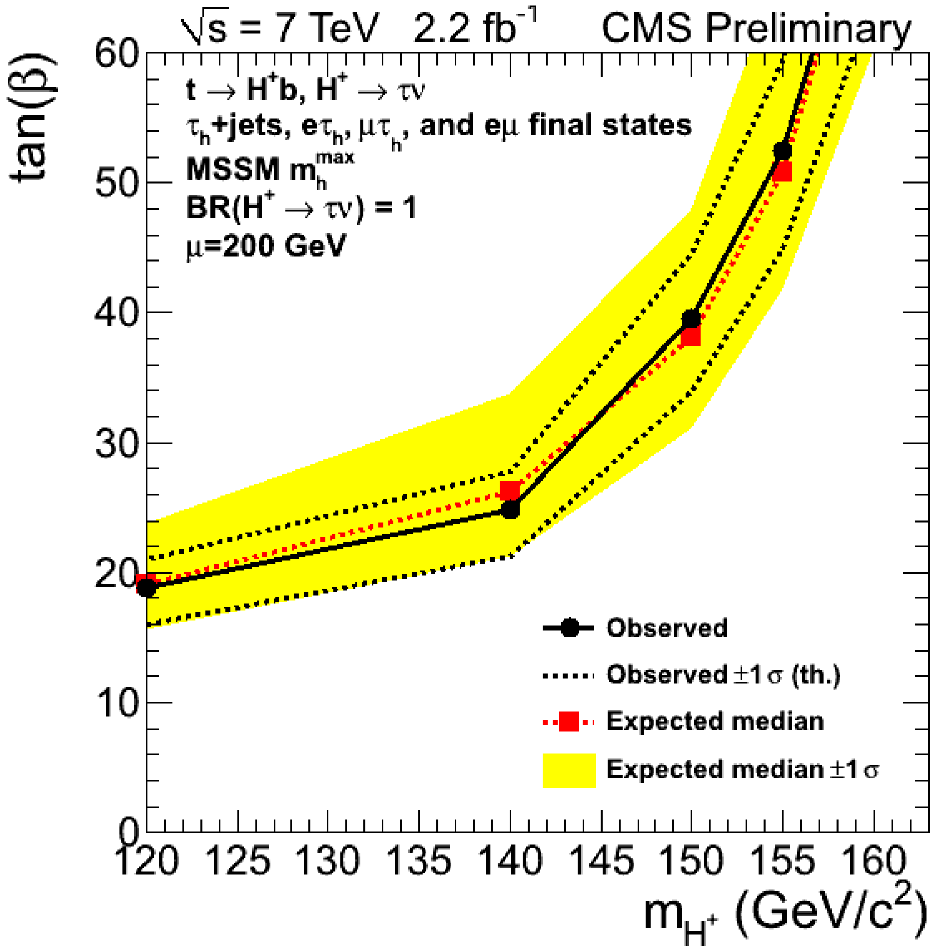


MuMu bound

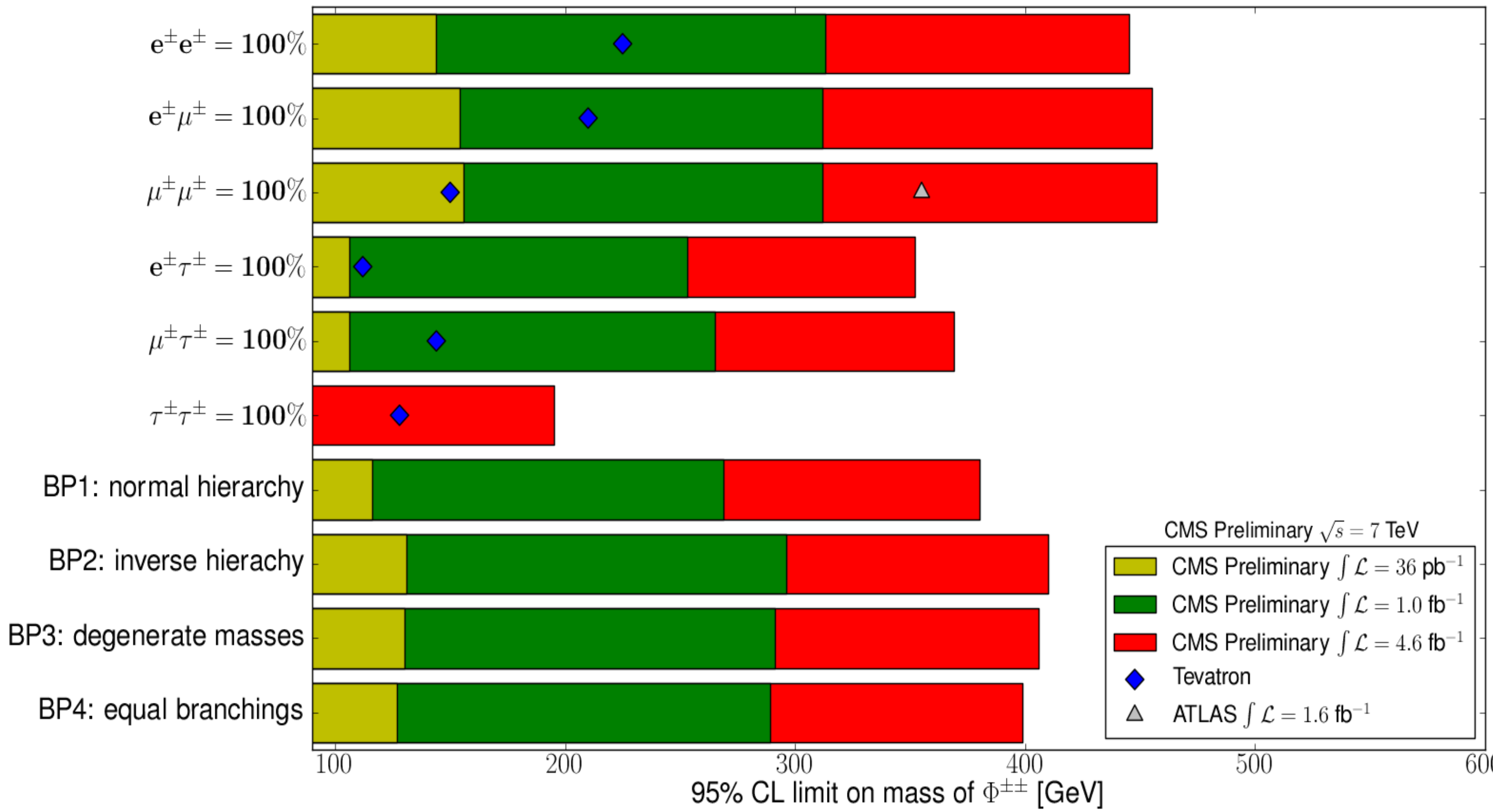


Observed
Expected ± 1σ
Expected ± 2σ
CMS preliminary, √s = 7 TeV
L_int = 1.3 fb^-1
Upper limit on σ(pp→ a → μμ) [pb]
M_μμ [GeV]
0
2
4
6
8
10
12
14
5.5
6
6.5
7
7.5
8
8.5

Charged MSSM Higgs boson bound



Mass bounds for doubly charged Higgs boson



4.Search for new physics beyond SM and MSSM(Exotica)

There are a lot of models:

- Additional dimensions
- Additional gauge bosons
- Heavy neutrino
- Scalar leptoquarks
- Compositeness
- ......
- ......

Additional dimensions

- In ADD(Arkani-Hamed, Dimopoulos,Dvali) model gravity lives in (4+d) -space-time, observable world lives on 4-brane. After compactification on torus of d additional dimensions

  $M^2_{PL} = V_d M_D^{2+d}$, $\quad V_d = (2\pi R_c)^d$

  If $M_D \sim 1$ TeV → $R_c^{-1} = (10^{-3}$ eV – 10 MeV) for $d = 2 – 6$. The masses of KK gravitons

  $m_n \sim (n^a n^a)^{1/2} R_c^{-1}$, $n^a = (n_1, \ldots n_d)$
- Graviton mass splitting $\Delta m \sim R_c^{-1}$

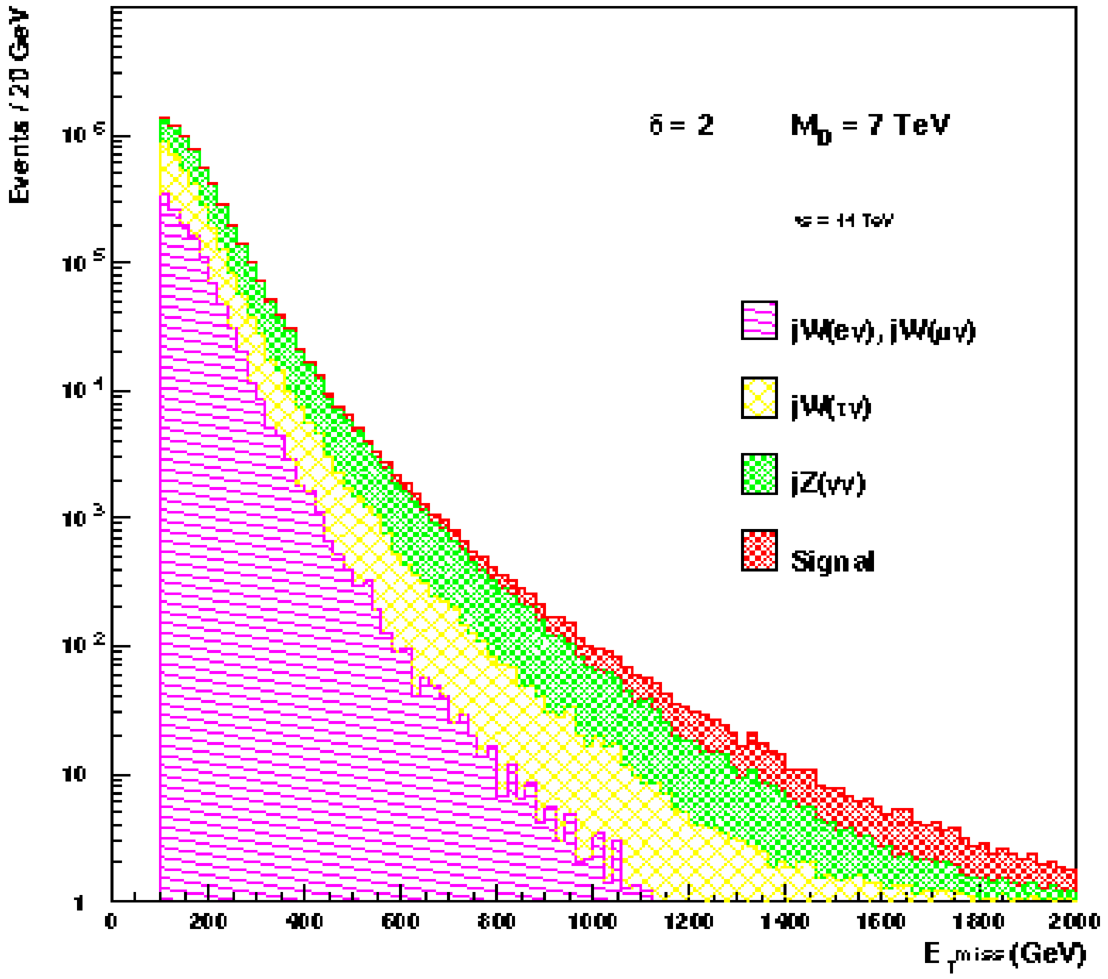
ADD model

- We have an almost continuous spectrum of gravitons which behave as massive stable noninteracting spin 2 particle
- Supercollider signature

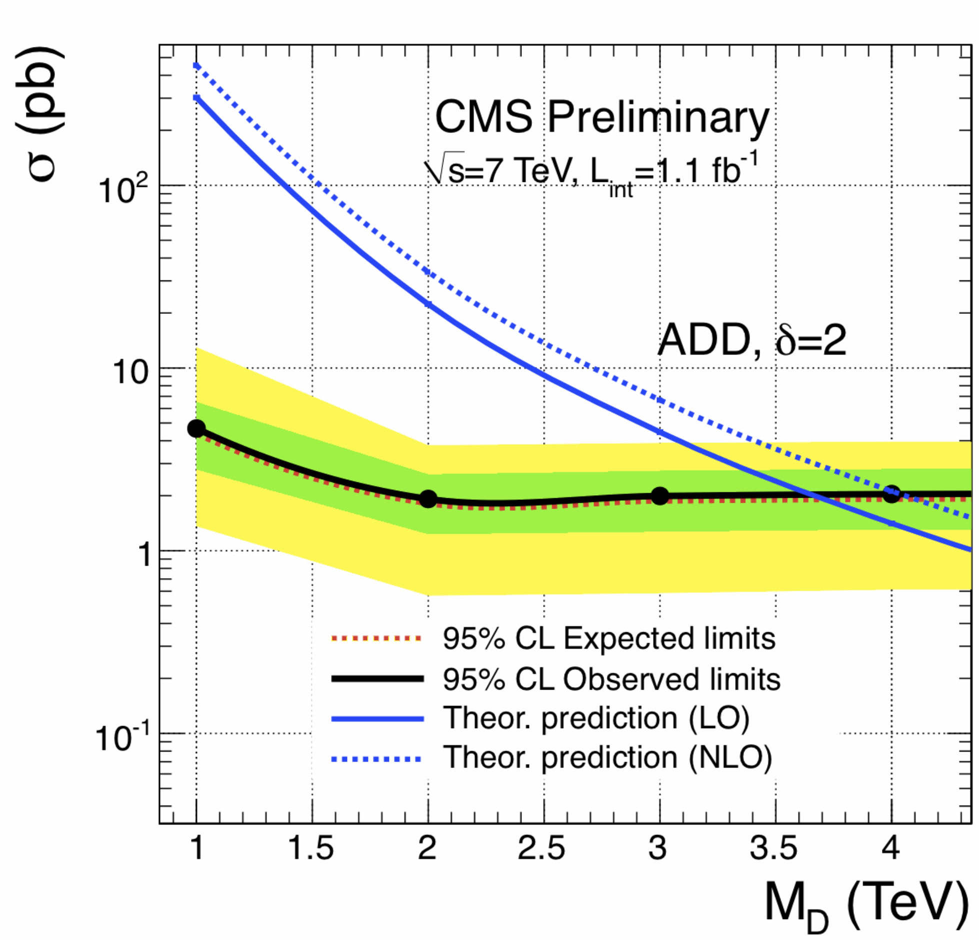
  $qg \rightarrow q\, G^{(n)}$ at parton level and

  $pp \rightarrow jet + E_T^{miss}$ at particle level .
- For $d = 2$ R_c^{-1} can be probed up to 10 TeV. The contribution of ADD massive gravitons contributes into DY cross section that allow to restrict $R_c^{-1} > 8$ TeV

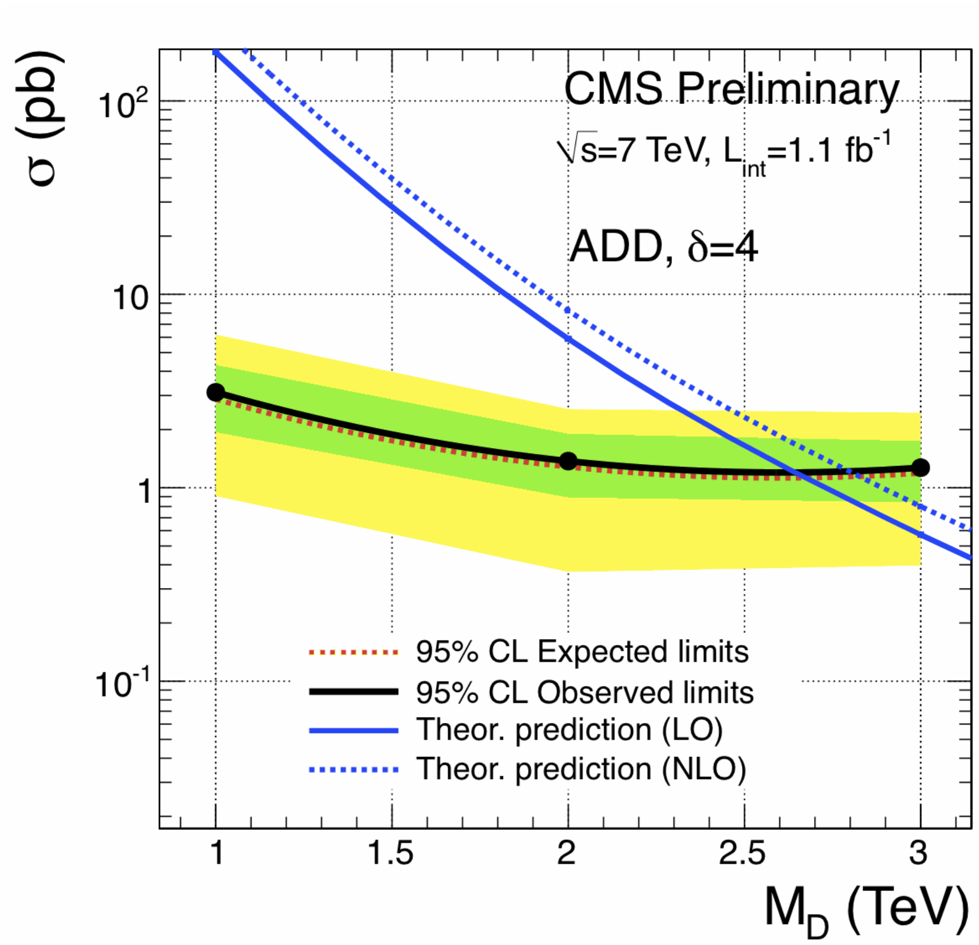
Distributions for missing transverse energy for ADD model



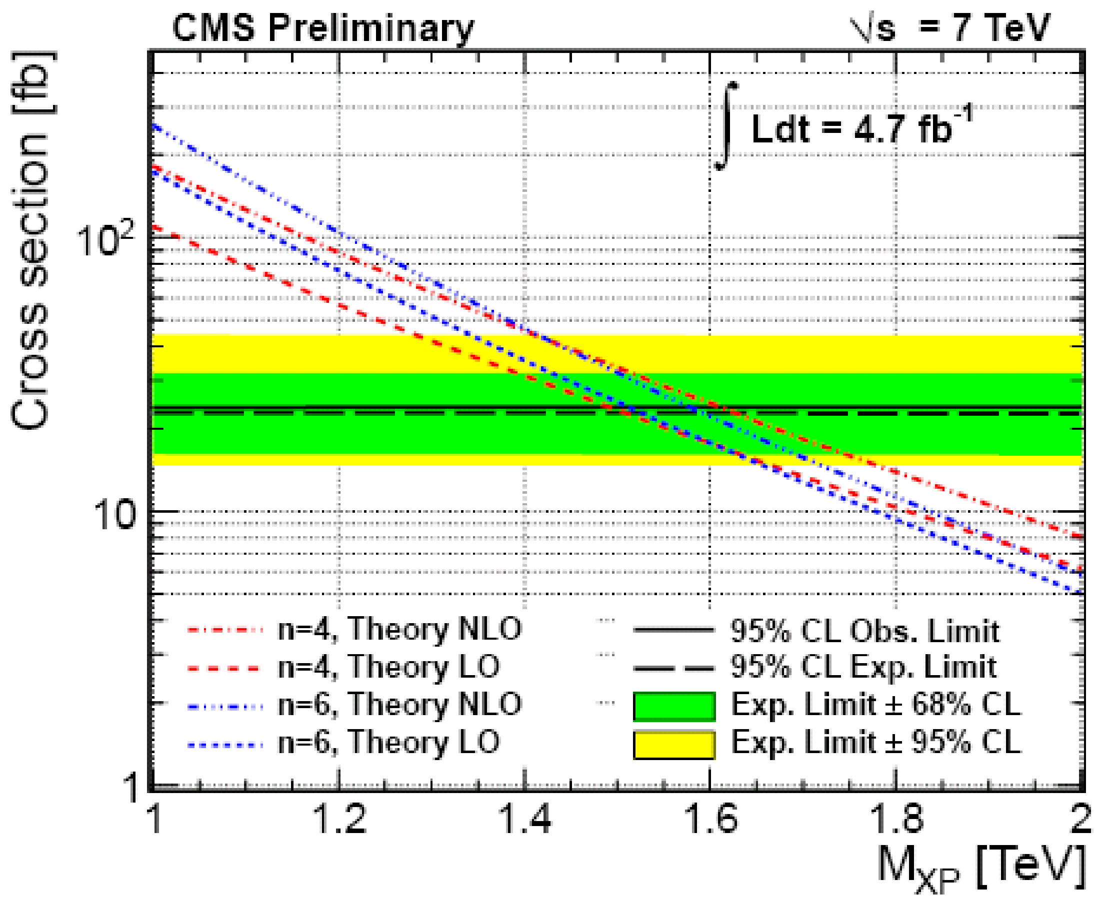
ADD bound for delta =2



ADD bound for delta =4



Photon +E^miss_T ADD bound



RS model

- In RS model (Randall-Sundrum) gravity lives in a 5-dimensional Anti-de Sitter space with a single extra dimension compactified to the orbifold S^1/Z_2

  The metric is

$$ds^2 = e^{-2k[y]}\eta_{\mu\nu}dx^\mu dx^\nu + dy^2 ..., y = r_c\theta$$

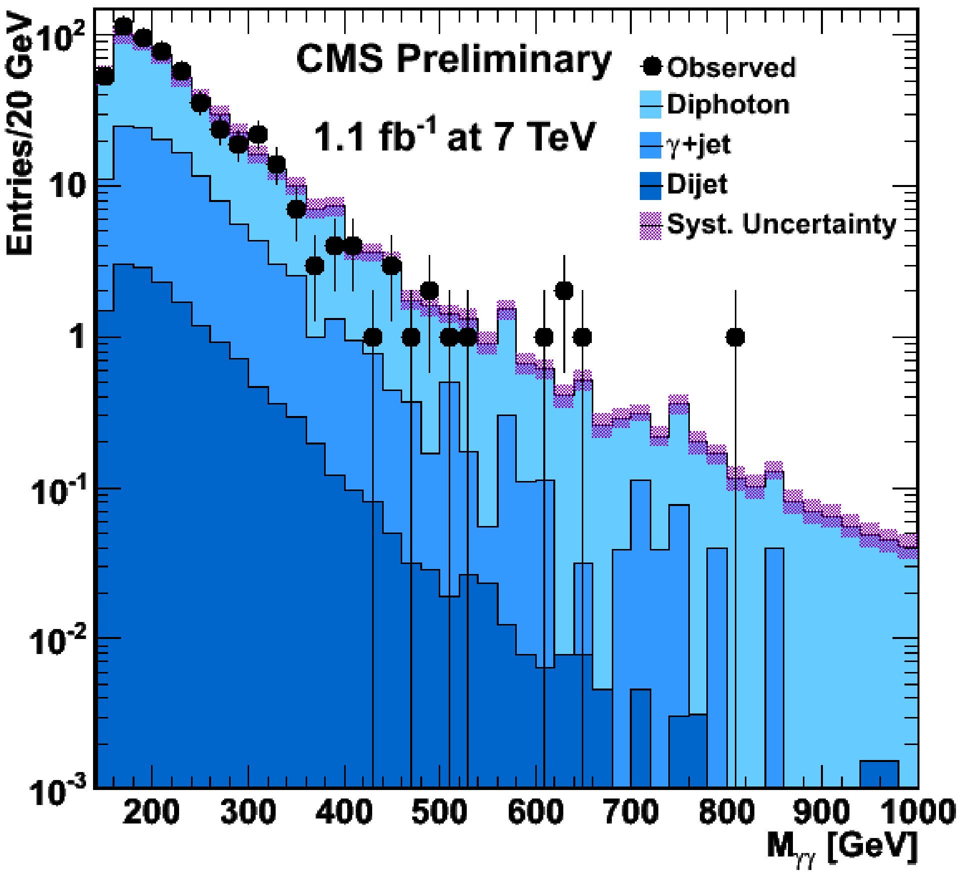
$$M_{PL}^2 = \frac{M_5^3}{k}(1 - e^{-2kr_c\pi})$$

There are two 3-dimensional branes (TeV brane,our world) and Planck brane

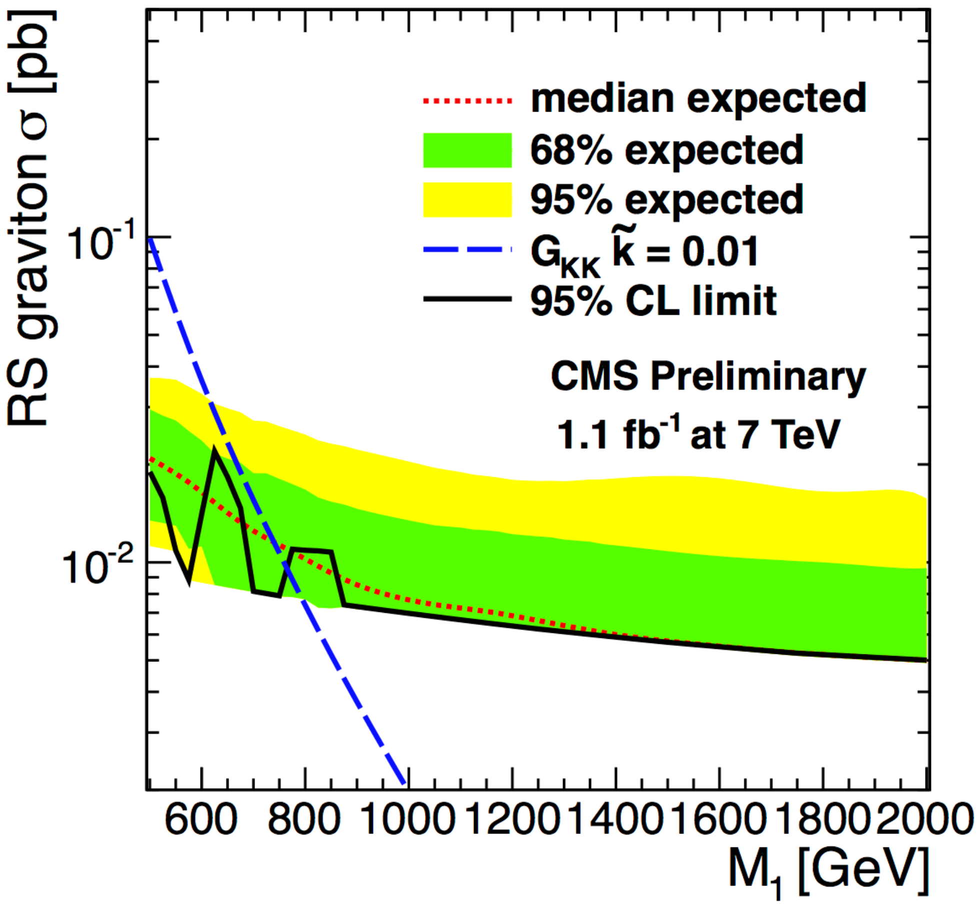
RS model predictions

- The main prediction of the RS model –
  KK excitations with $m_{gr}(1) \sim$ O(1) TeV
  The most promising signature is
  $$q\bar{q}, gg \rightarrow G_{res,1} \rightarrow e^{+}e^{-}, \mu^{+}\mu^{-}$$
- The graviton resonance can be detected for
  $M_{gr}(1) <4$ TeV(14 TeV)
- Other conseqence → radion field (similar to Higgs boson, couples with trace of energy-momentum)

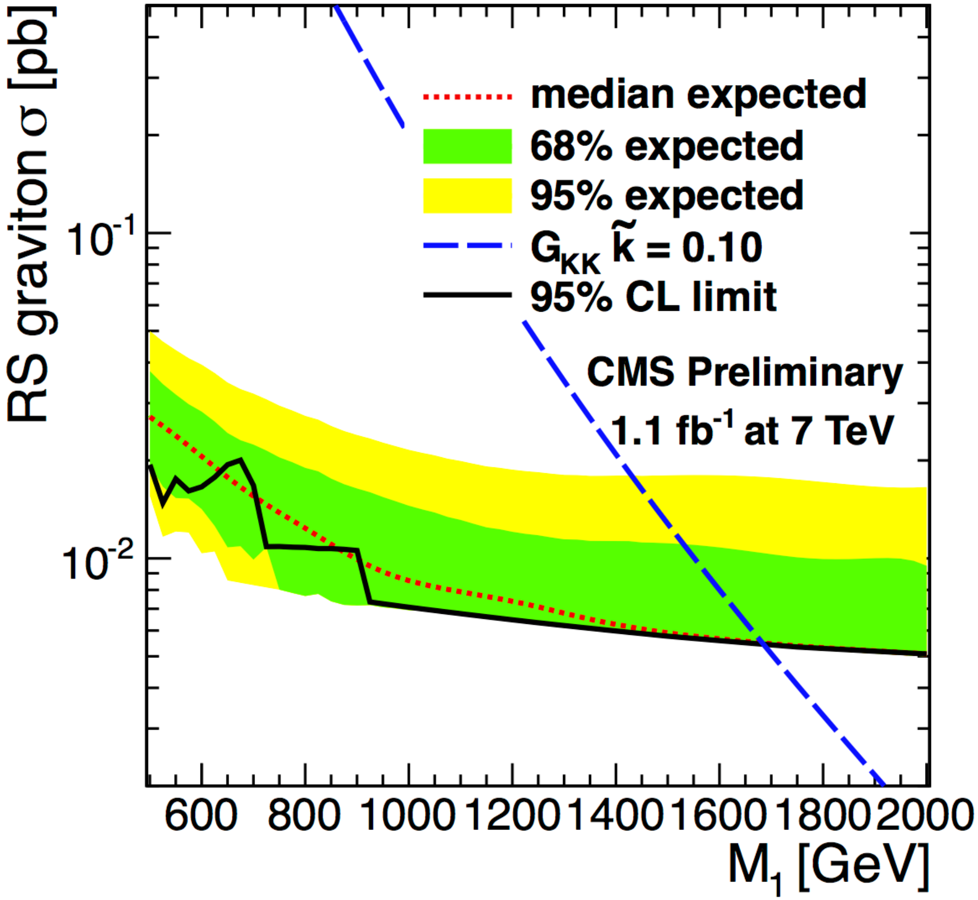
Diphoton mass spectrum



RS graviton resonance bound for k/Mpl=0.01(diphoton mode)



RS graviton resonance bound for k/Mpl=0.1(diphoton mode)



Additional neutral gauge bosons

- Additional gauge bosons arise in many extensions of SM containing additional

  U(1) gauge group. Such extensions arise

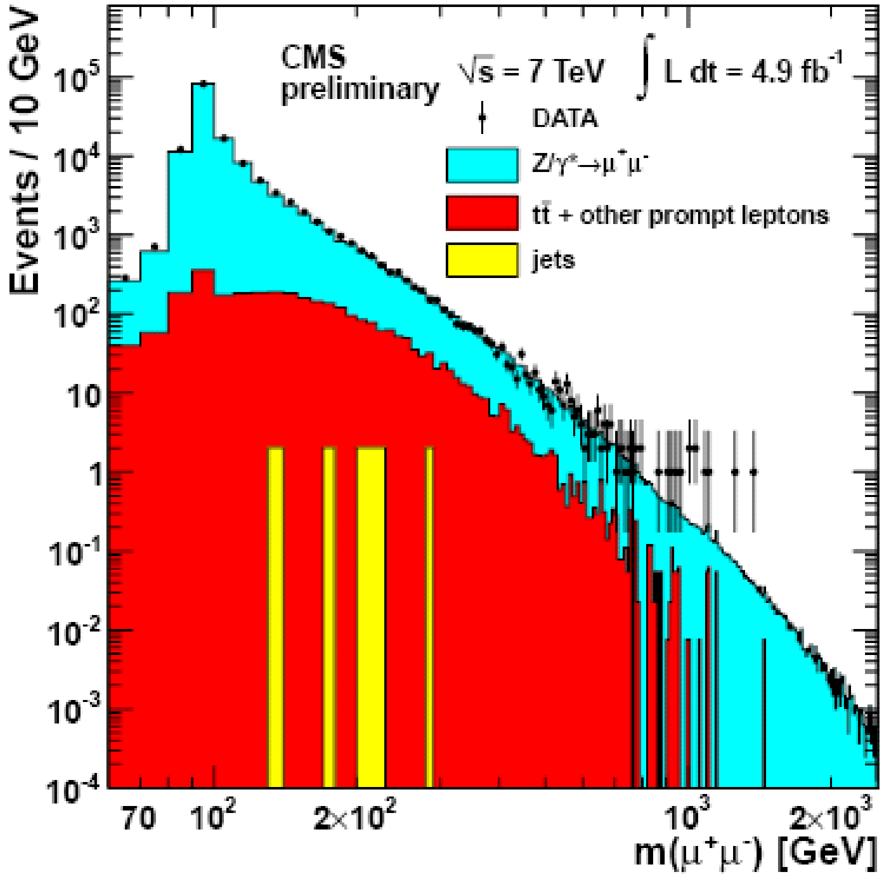
  in the context of SO(10) and E(6) gauge groups.

  The most promising way to discover Z'-boson is to use its leptonic modes $Z' \to e^+e^-, \mu^+\mu^-$

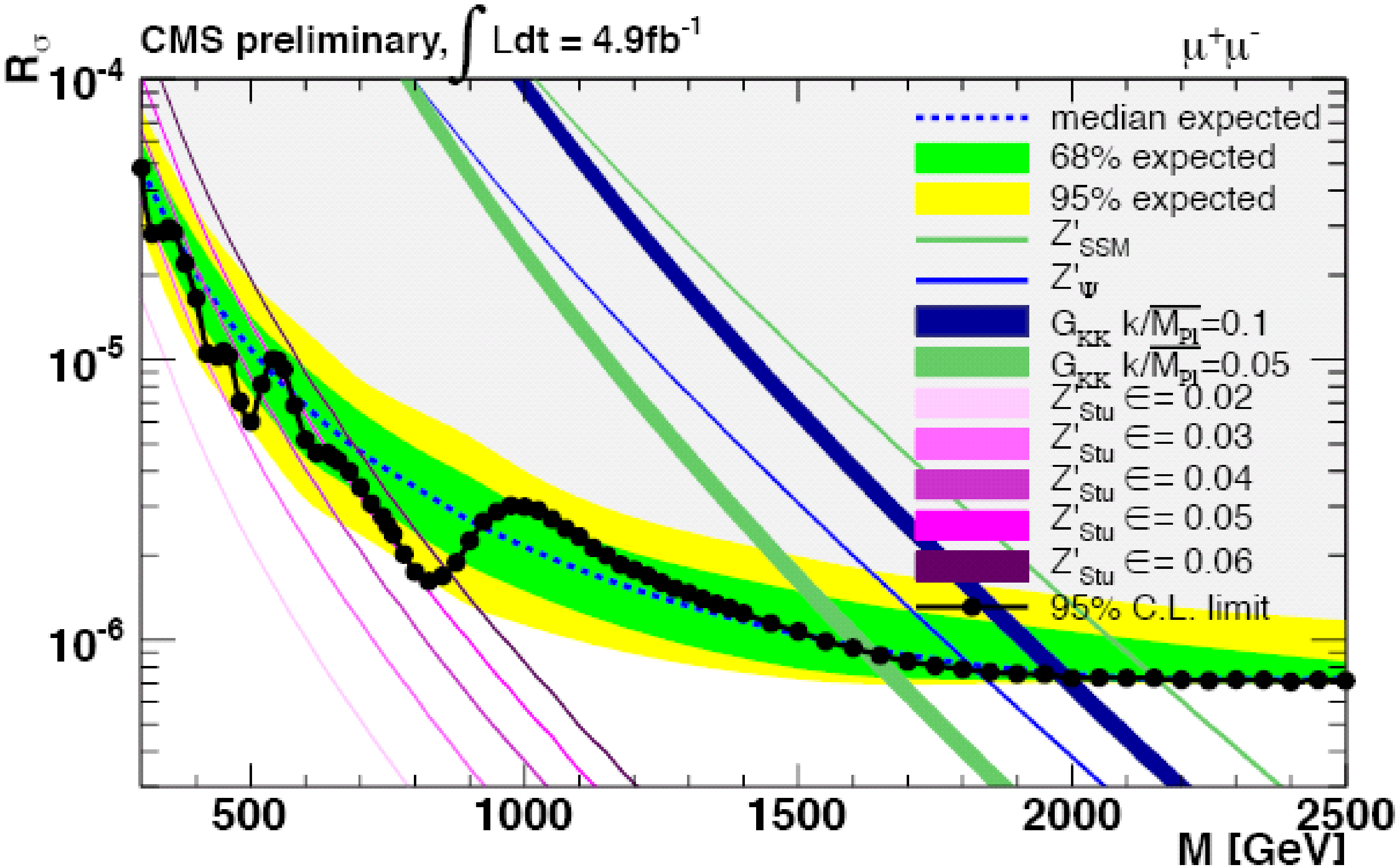
  The manifestation of the Z' boson is the resonance structure in DY process.

  It is possible to discover Z ' with a mass up to 4.3 TeV for L_{tot} = 100 fb^{-1} using dimuon mode

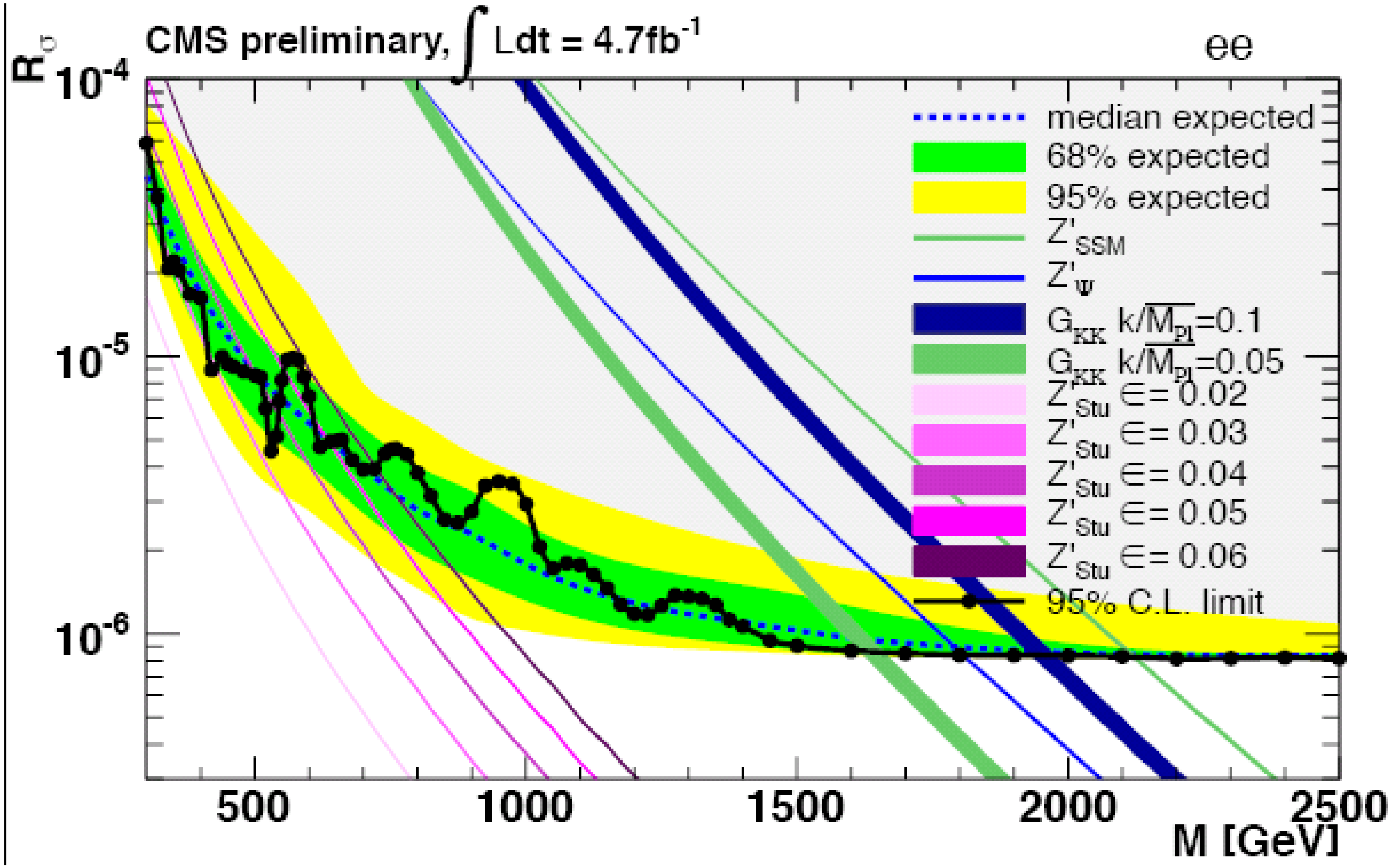
Distribution on (mu mu) invariant mass



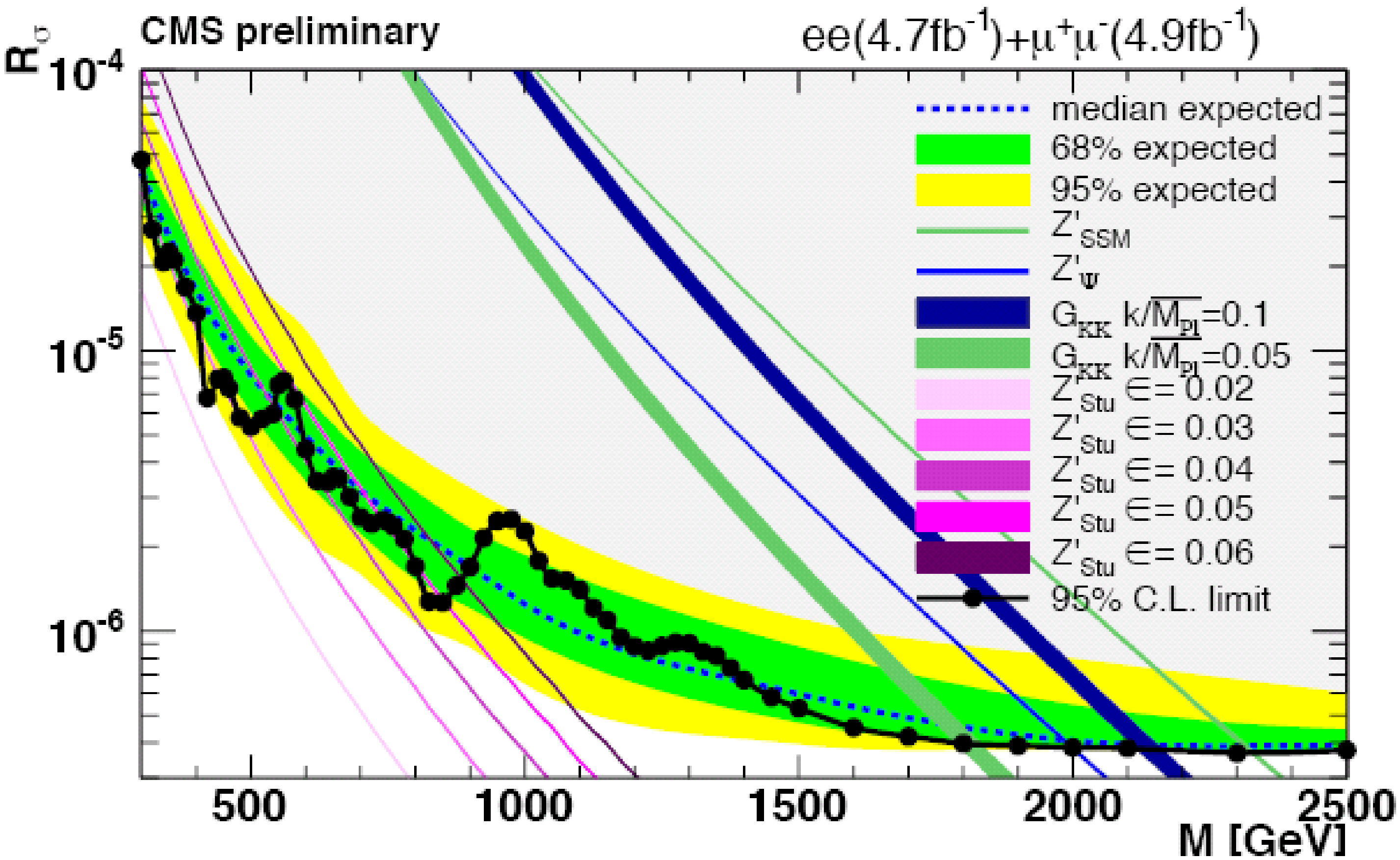
(Mu Mu) mass limit for different models



(e e) mass limit gor different models



(e e) + (mu mu) limit for different models



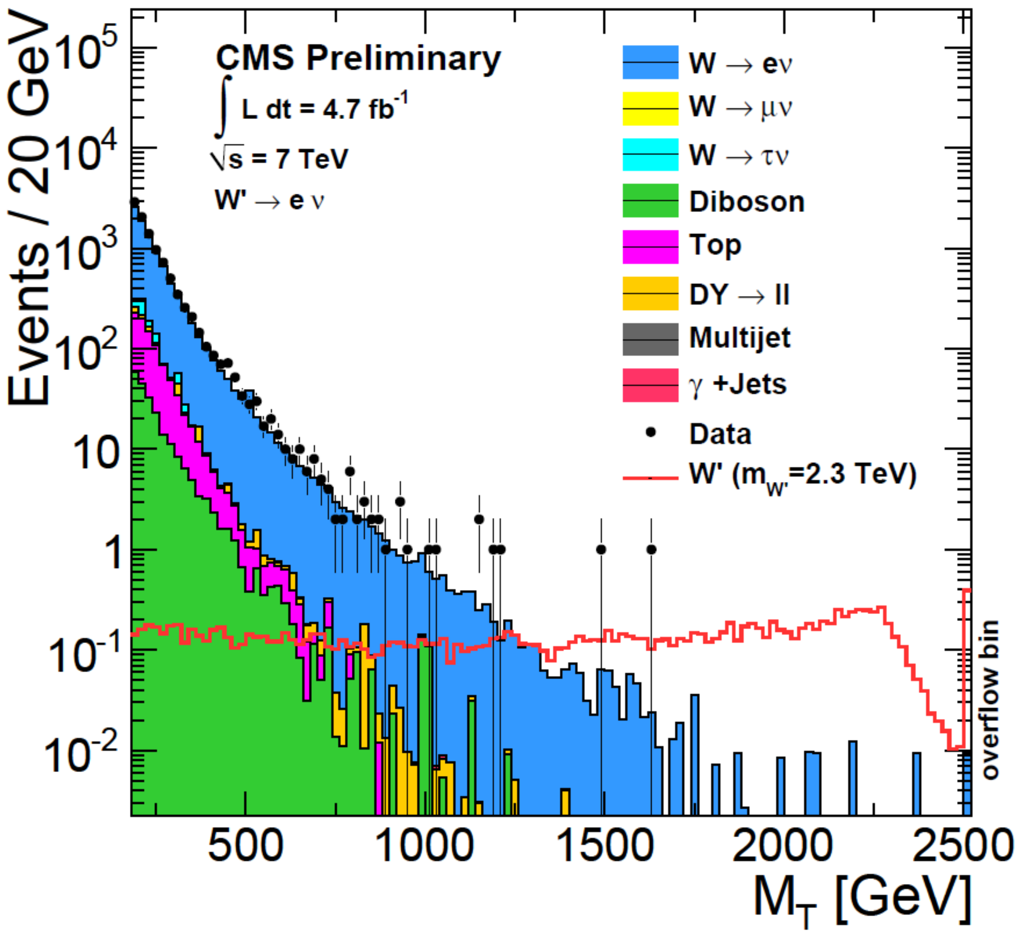
Additional W` bosons

- For model with heavy W` boson

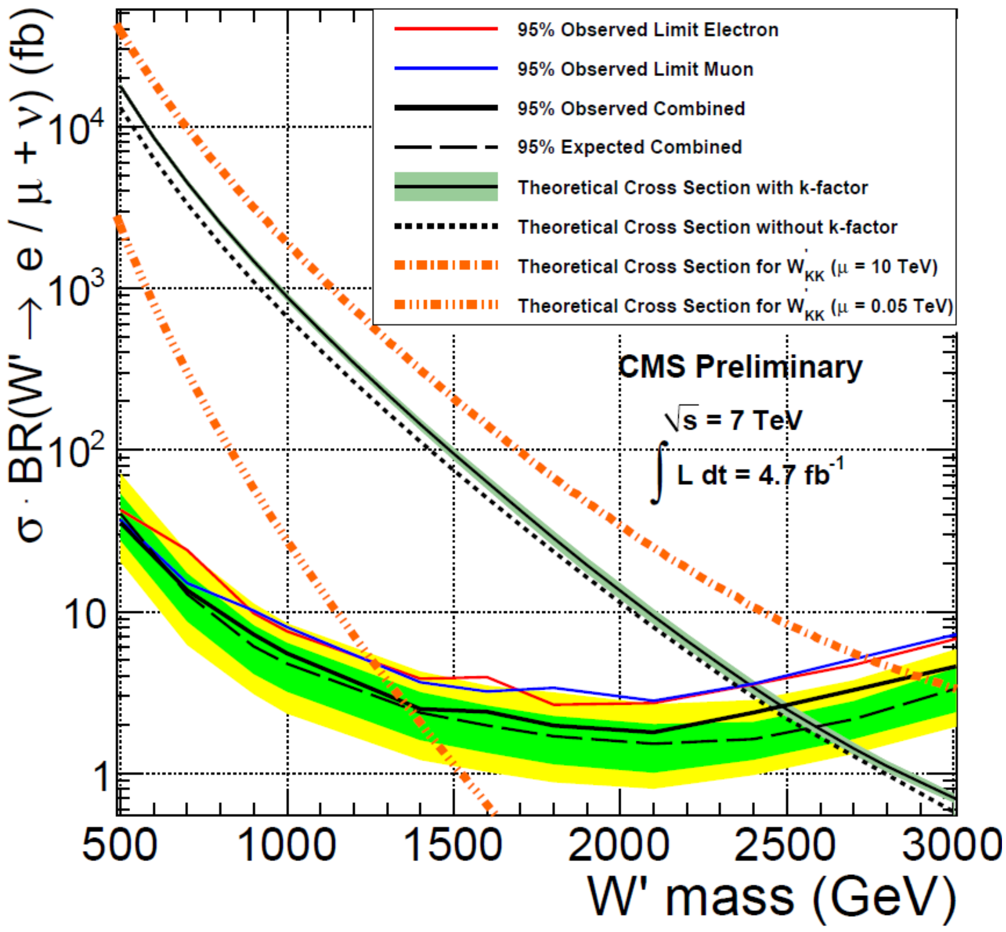
with decay modes as SM W boson

- W→l nu,
- W→ qq`
- The signature is isolated electron or muon plus missing transverse energy
- Backrounds: W-production and ttbar-production

Distribution on transverse mass



CMS limit on W` mass



Heavy neutrino and right W boson

- Left-right symmetric models based on

$$SU_c(3) \otimes SU_L(2) \otimes SU_R(2) \otimes U(1)$$

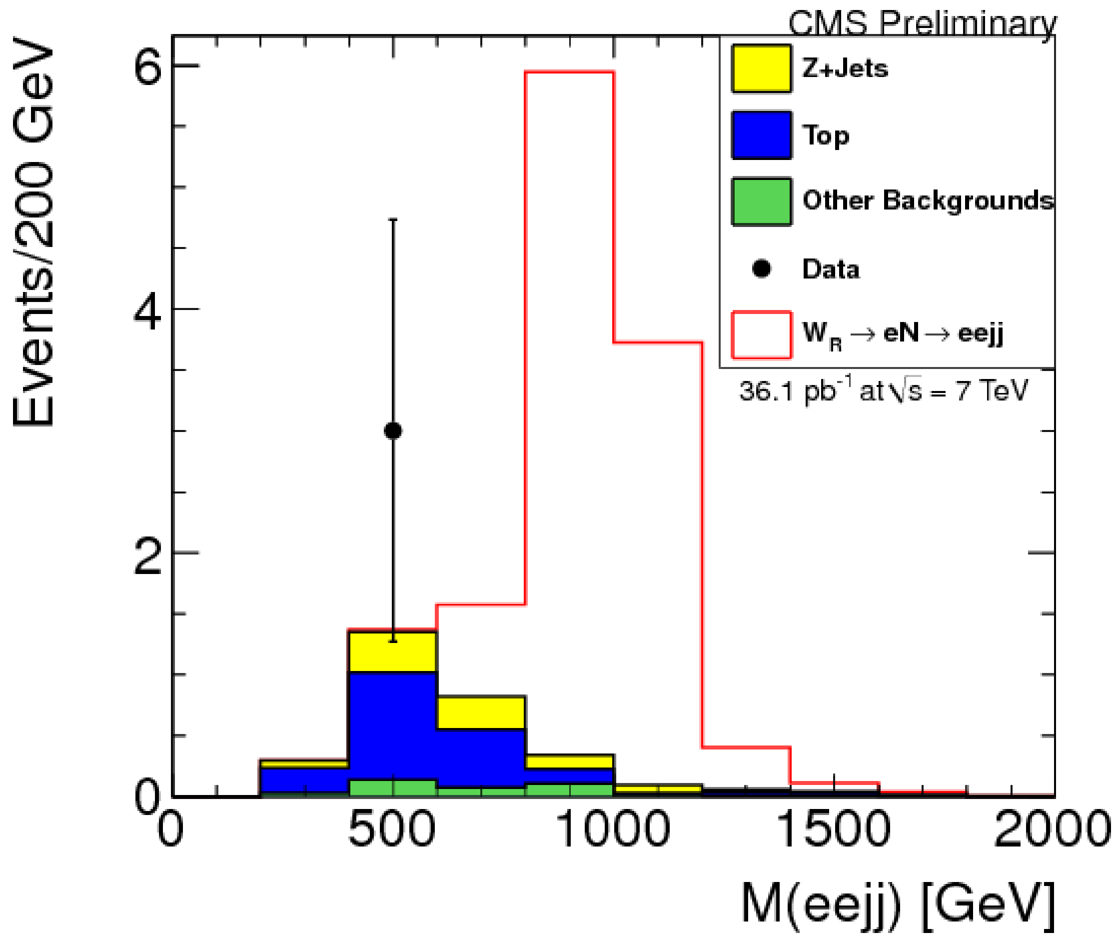
gauge group naturally include heavy Majorana neutrino. For heavy neutrino lighter than W_R -boson it is possible to look for heavy neutrino

in W_R decay using the signature

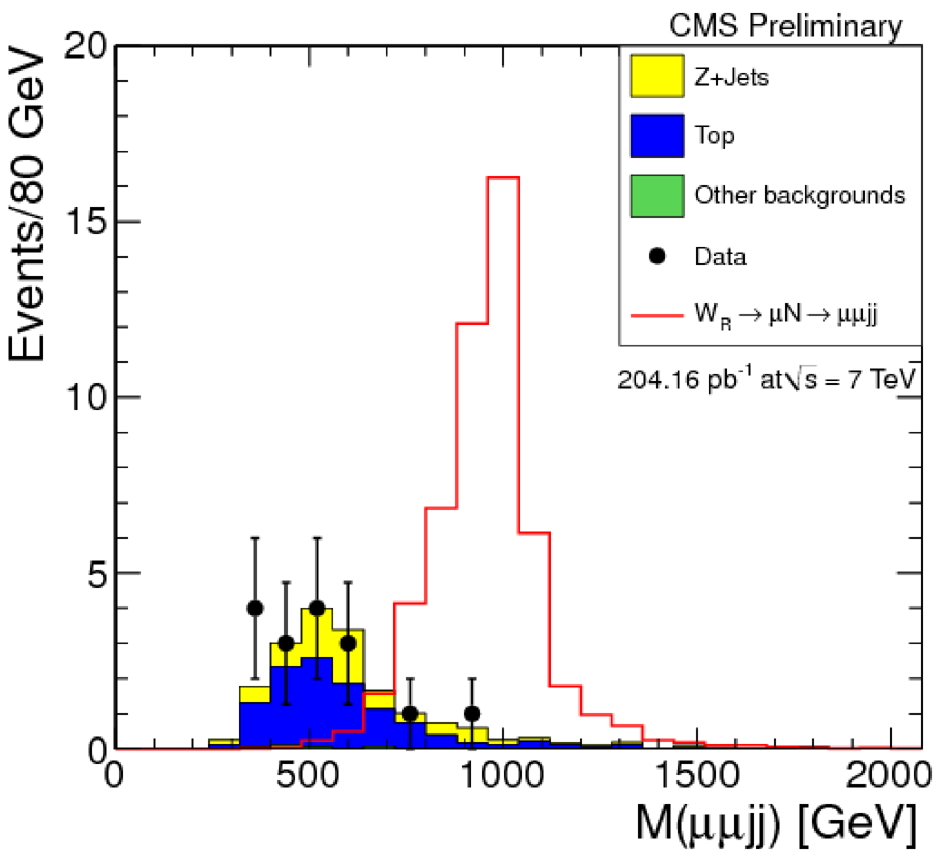
$pp \rightarrow W_R + ... \rightarrow e(\nu_{R,l} \rightarrow ejj) + ...$

Due to Majorana nature of neutrino halph of events will be with the same sign leptons .Signature- 2 is.leptons +two jets

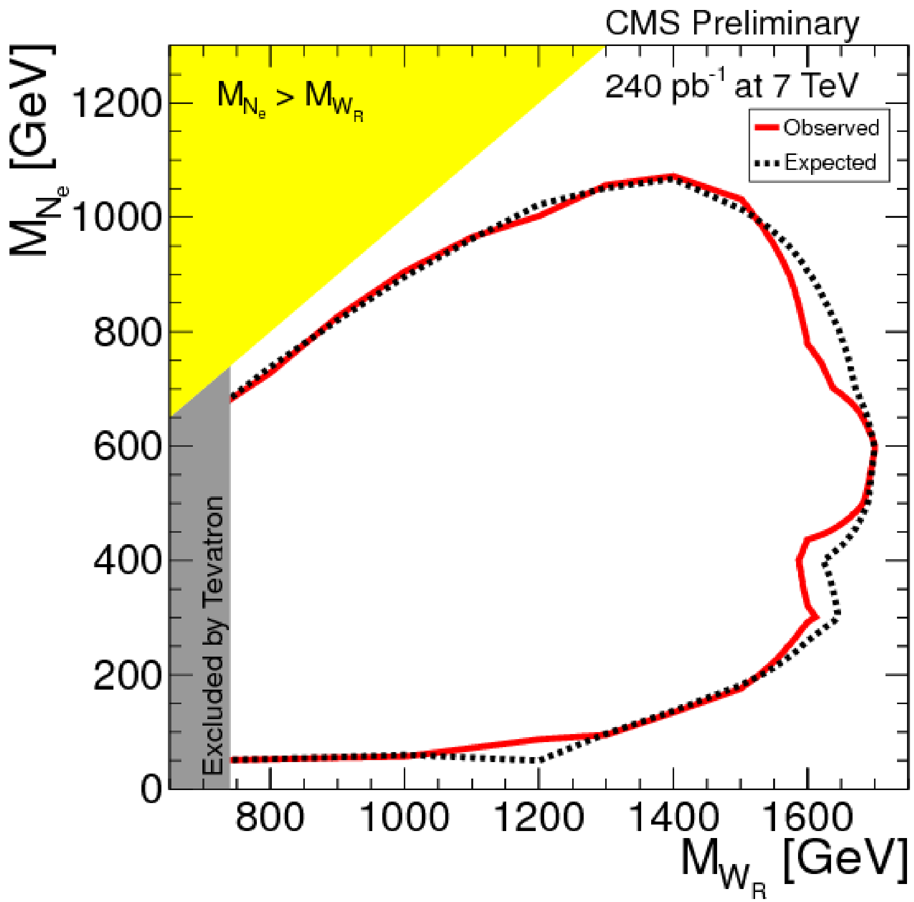
Distribution of eejj invariant mass



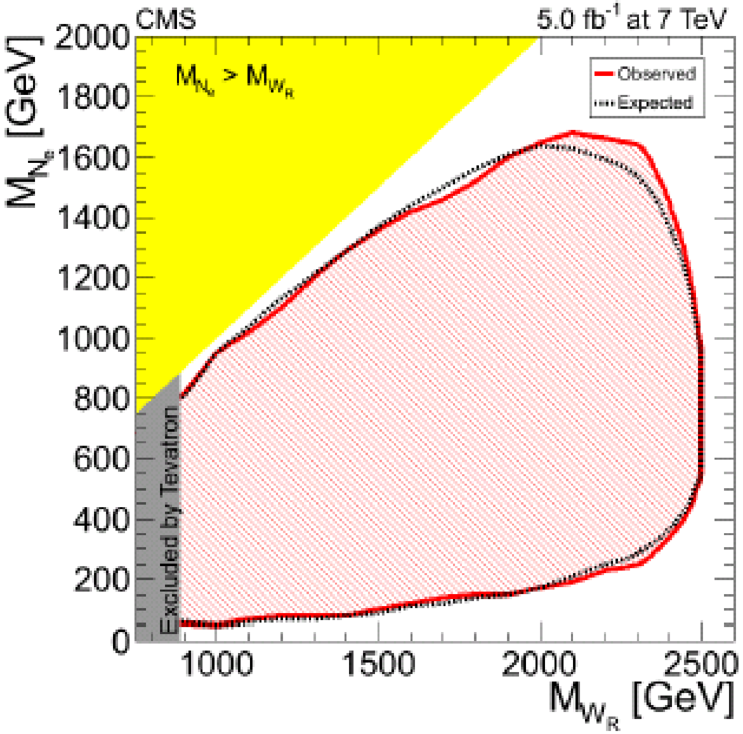
Distribution of (mu mu jet jet) invariant mass

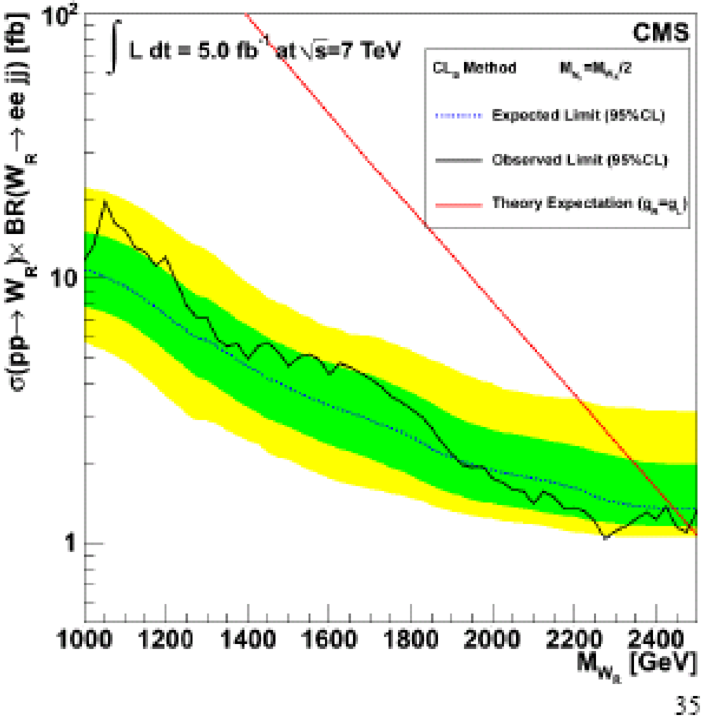


Bounds for heavy electron neutrino for 240 pb^-1 luminosity

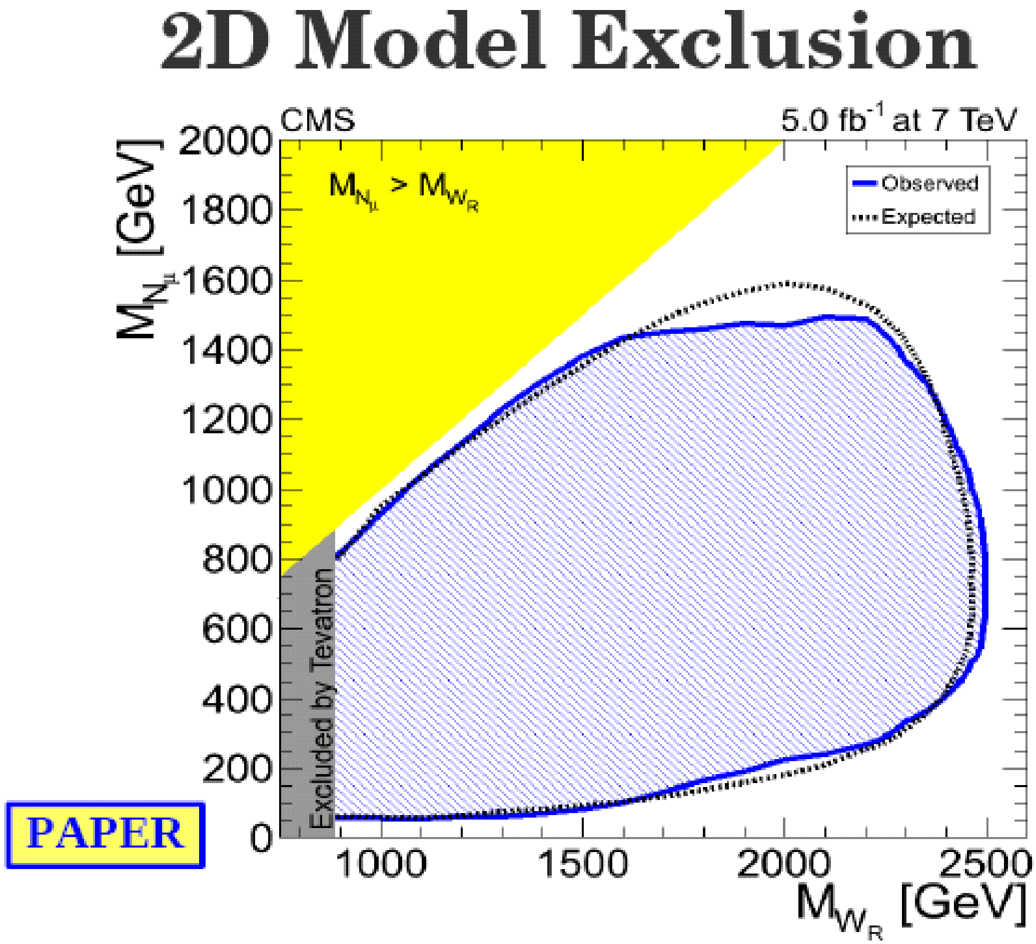


Bounds on heavy electron neutrino and W_R boson





Bounds on heavy muon neutrino and W_R boson



Scalar leptoquarks

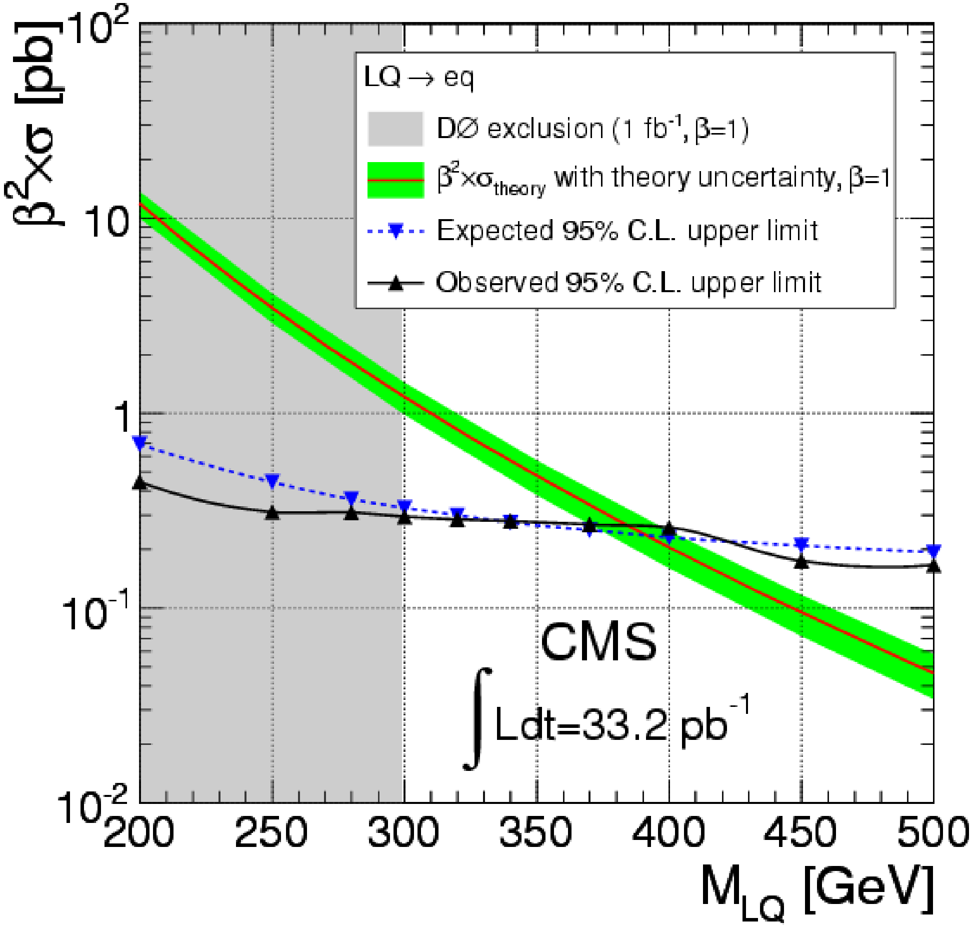
- Scalar leptoquarks (LQ) are particles having lepton,colour and baryon numbers different from zero. At LHC both single and pair leptoquark productions are possible
- g + g → LQ +l → 2l + q
- g +g → LQ + LG → 2l + 2q

Scalar leptoquarks

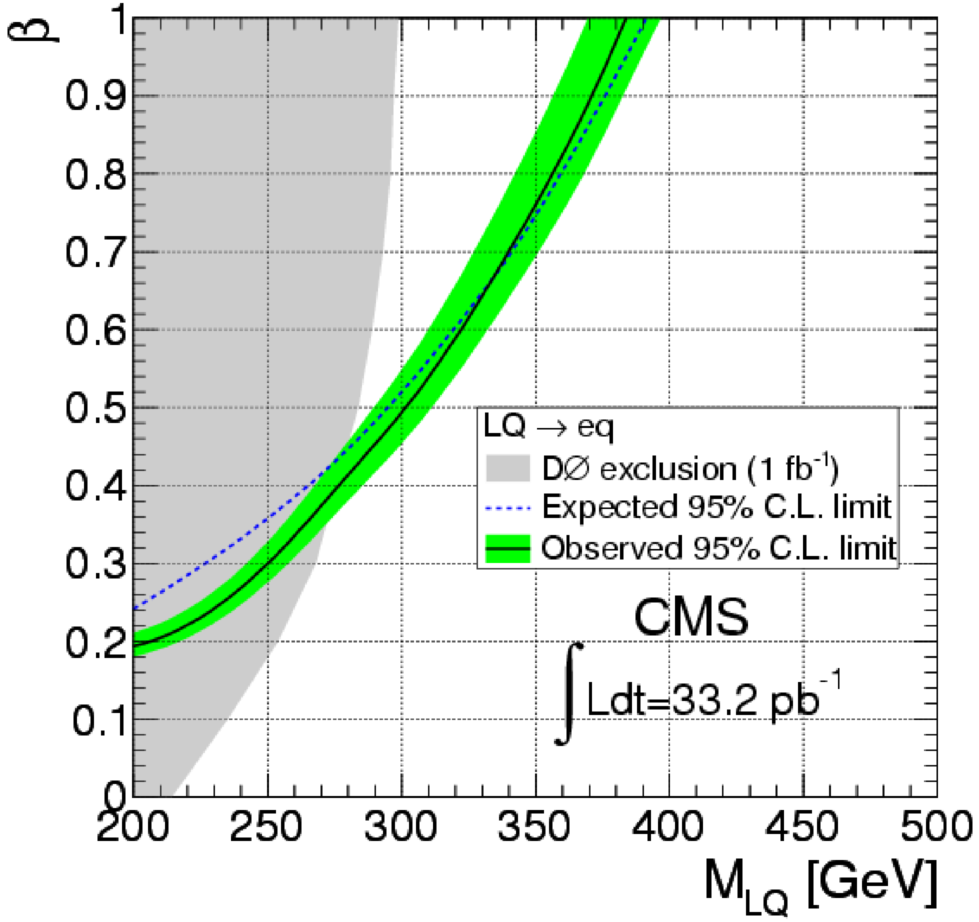
- For pair leptoquark production the main signature are events with

    2 jets and 2 isolated leptons

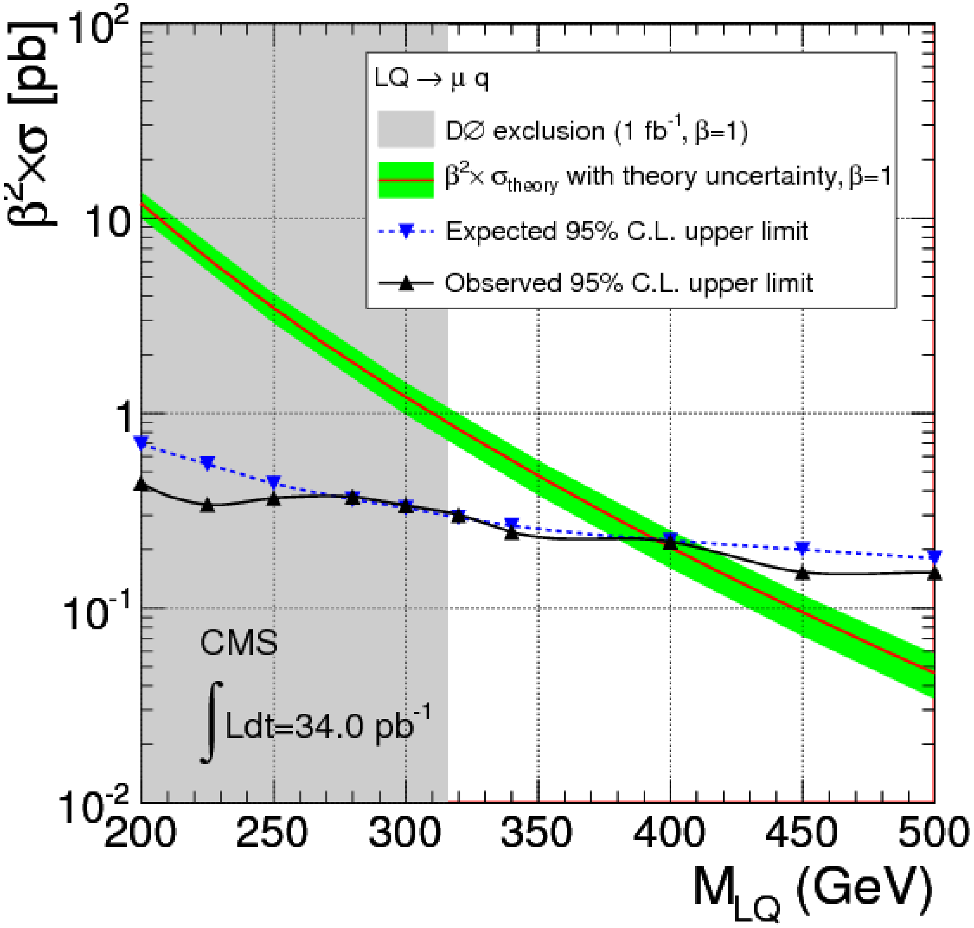
1 st generation leptoquark bound



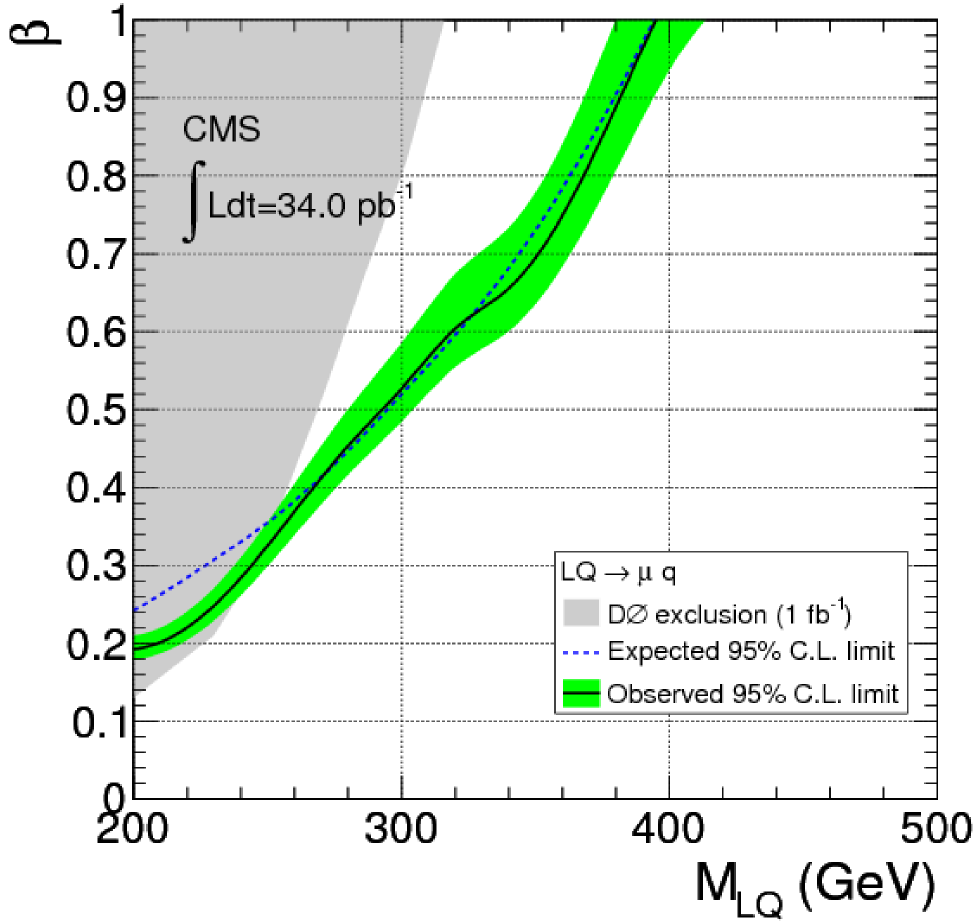
1 st generation leptoquark bound



2 nd generation leptoquark bound



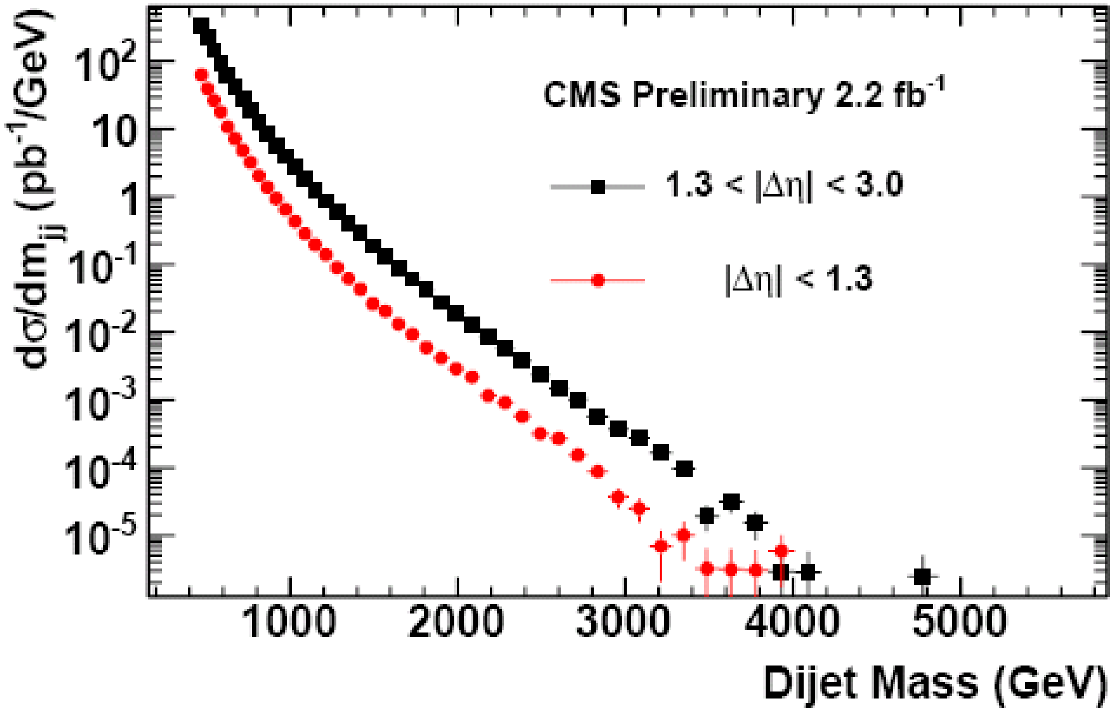
2 nd generation leptoquark bound



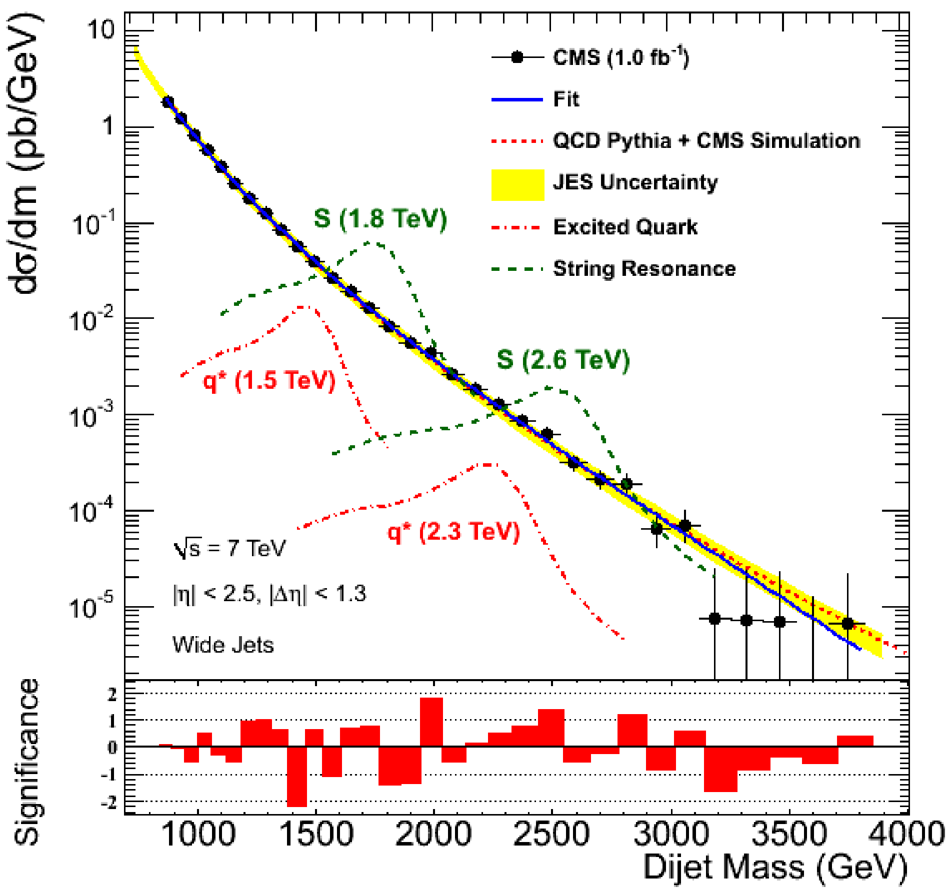
Search for dijet resonances

- A lot of models
- At quark gluon level
- qq→Resonance →2 jets
- qg→Resonance →2 jets
- gg→Resonance→2 jets
- Signature: resonance structure in dijet mass distribution

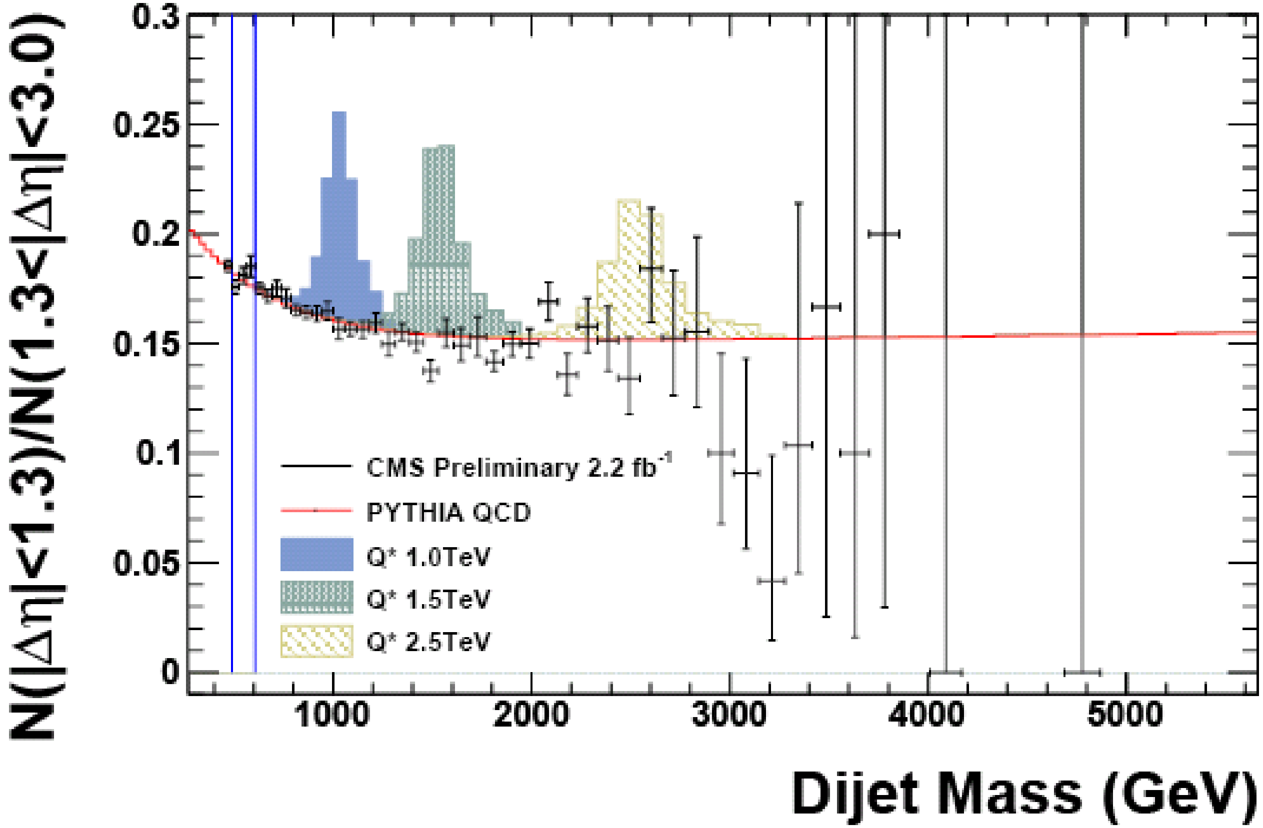
Search for resonances in dijet mass spectrum



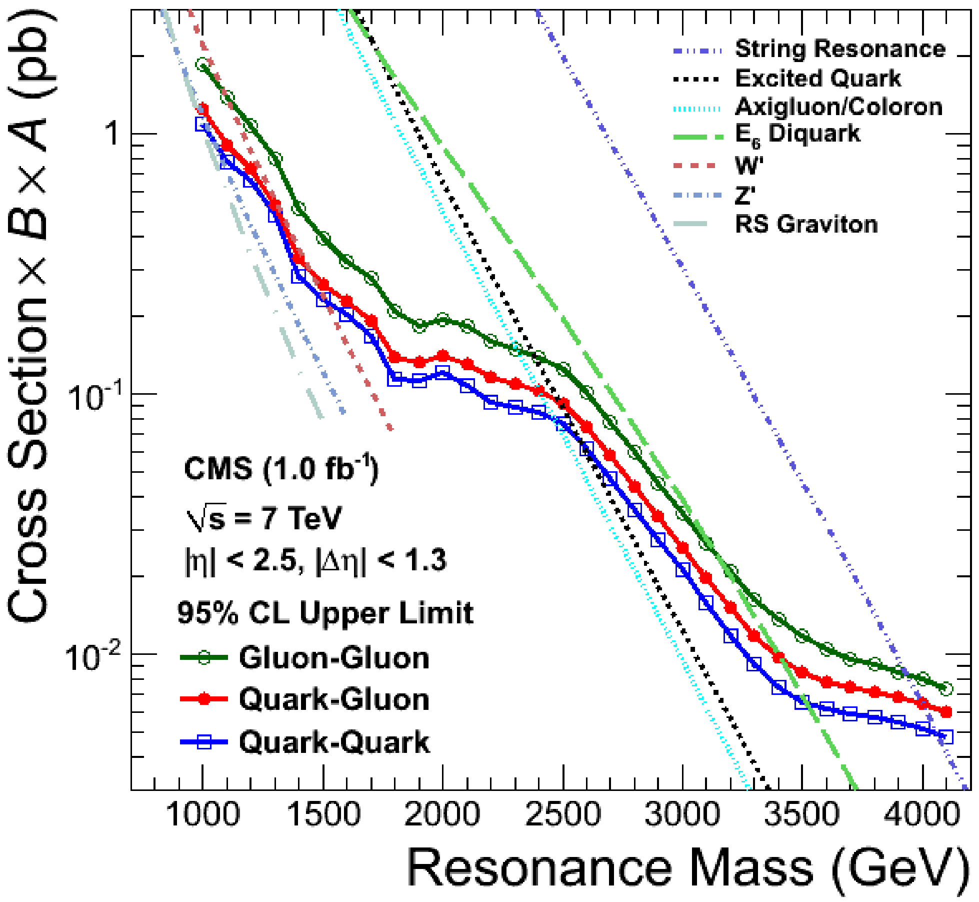
Dijet mass cross section distribution



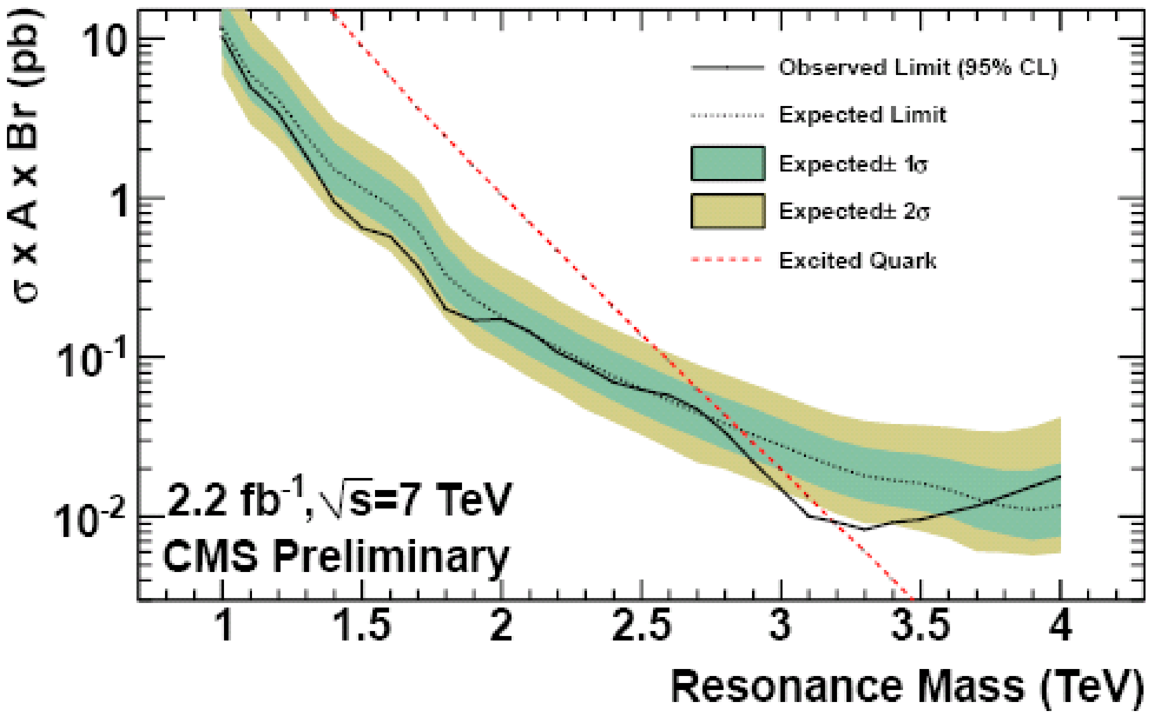
The ratio of jet cross sections for different eta regions



Cross section resonances bounds



qg resonance bounds



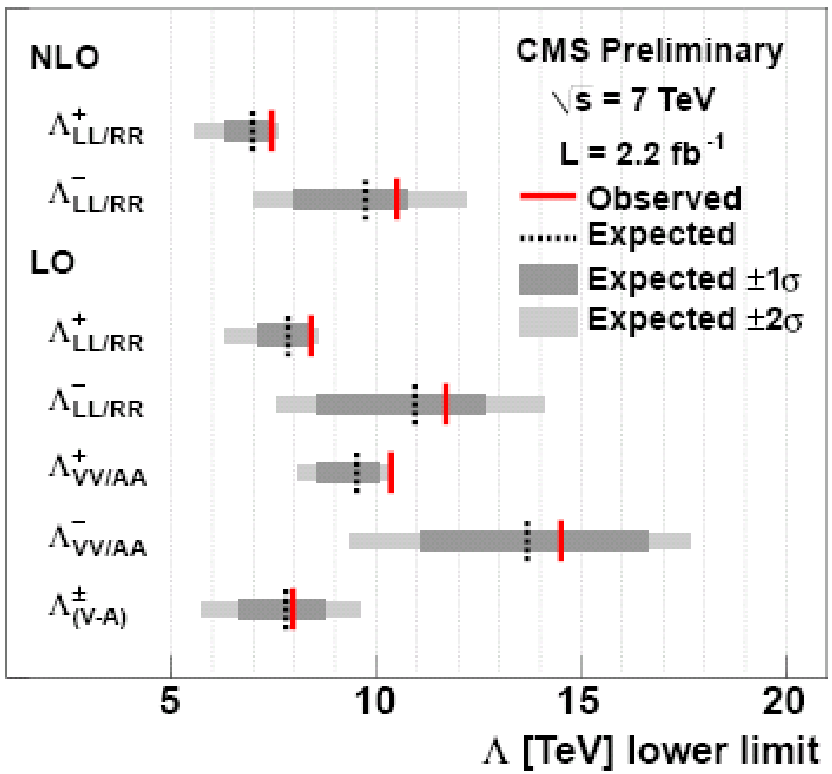
Mass bounds for some models

Model	Excluded Mass (TeV)	
	Observed	Expected
String Resonances	4.00	3.90
E_6 Diquarks	3.52	3.28
Excited Quarks	2.49	2.68
Axigluons/Colorons	2.47	2.66
W' Bosons	1.51	1.40

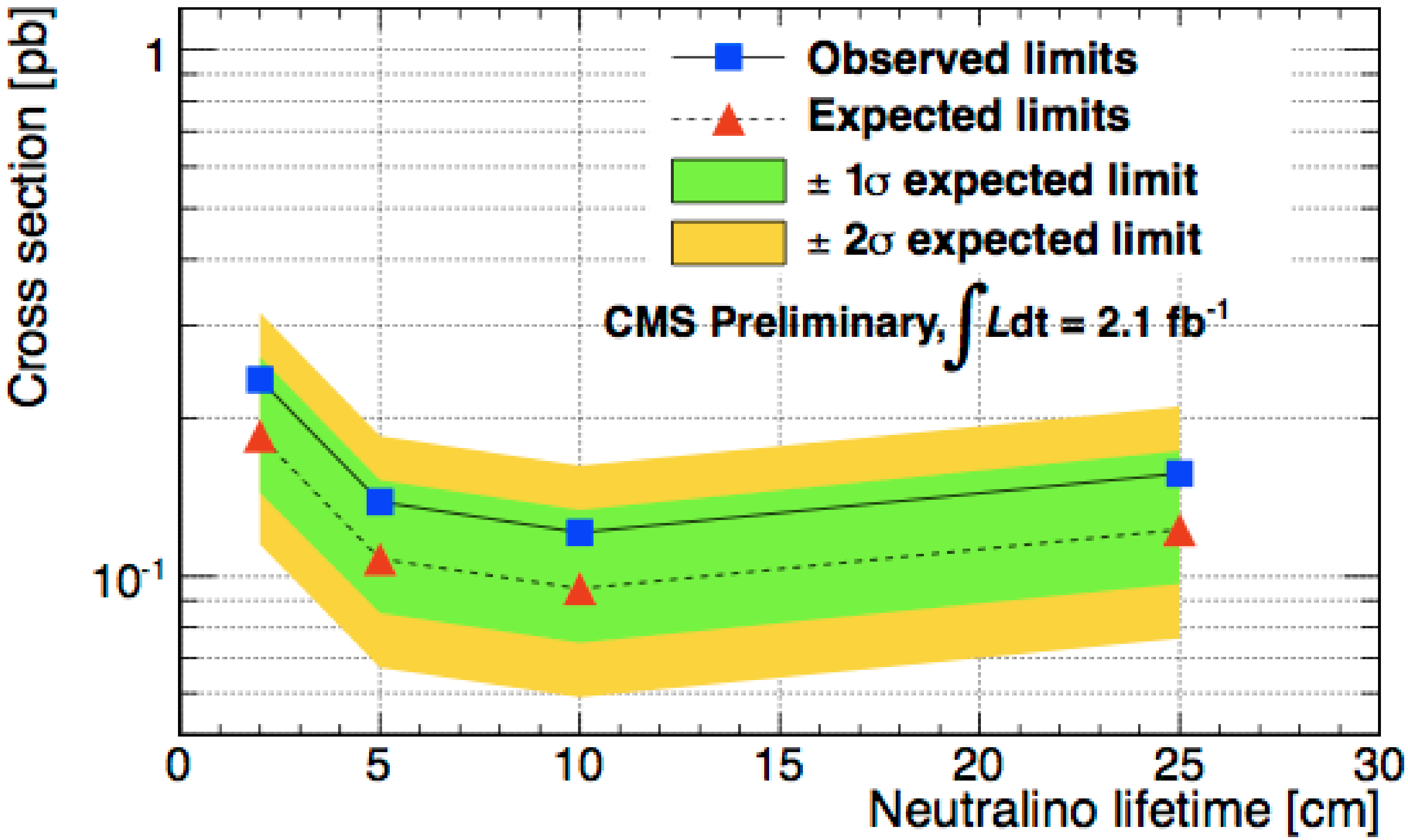
Compositeness

- If squarks and leptons are composite particles made from “preons” we can expect deviations from SM predictions for high p_T cross sections (Drell-Yan, jet cross sections). At $L_{tot} = 100\ fb^{-1}$ LHC will be able to probe point like stucture of quarks with a scale up to 20 TeV

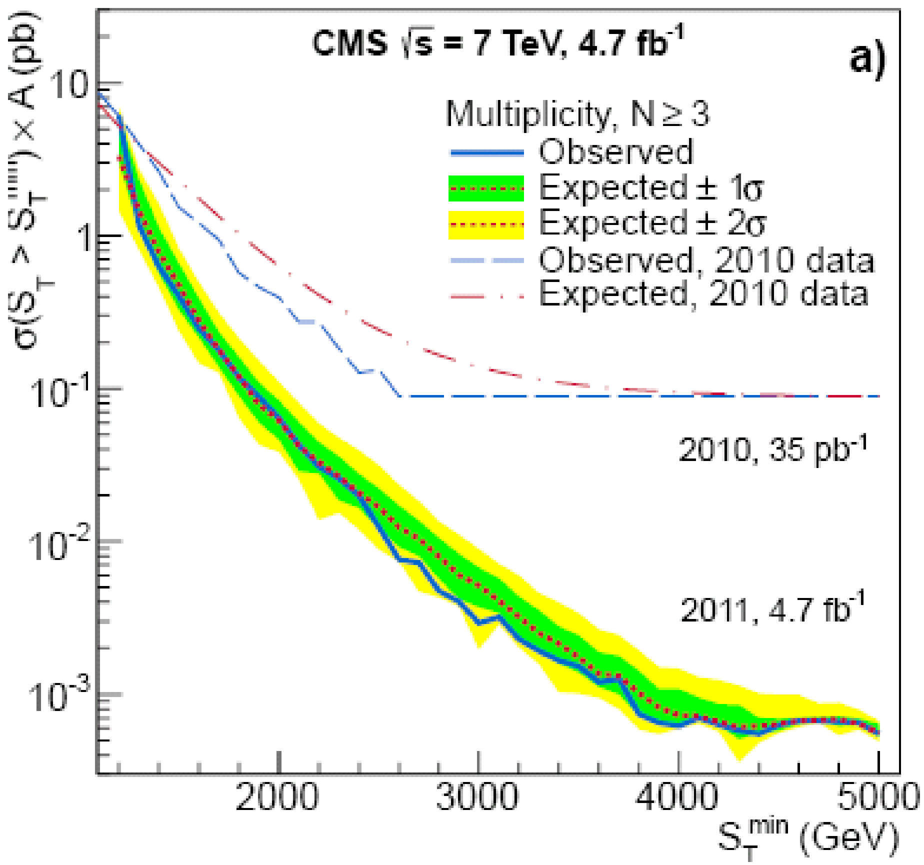
Limits on parameters of contact interactions



New long-lived particles photon decays

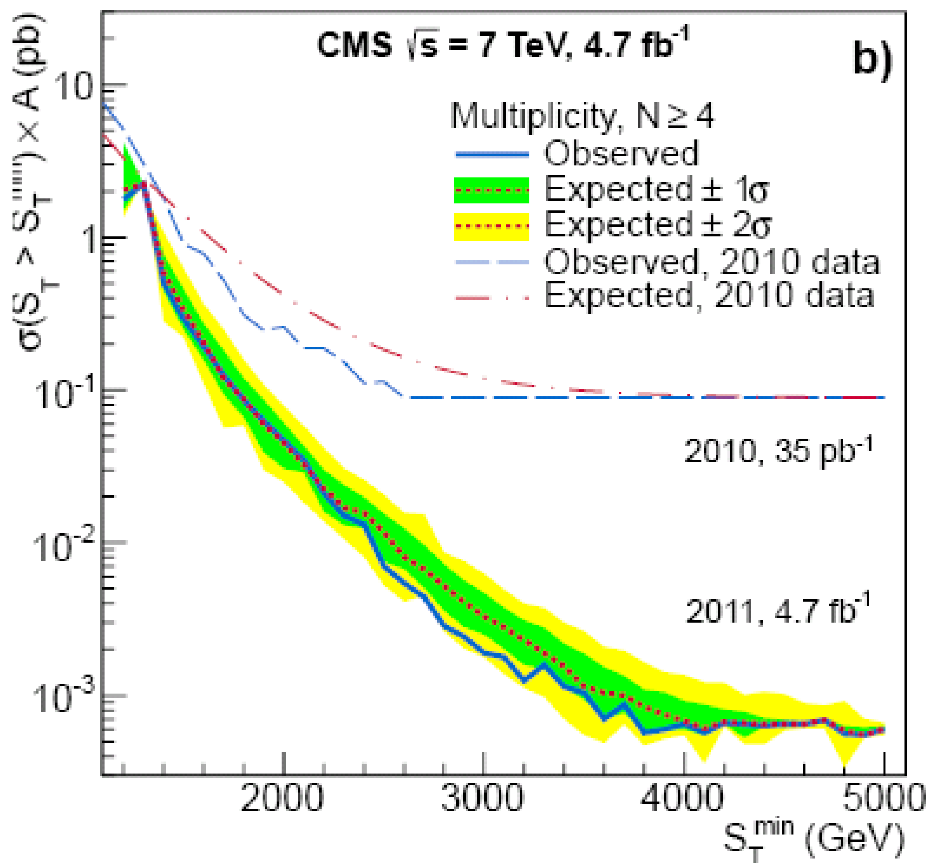


Black holes



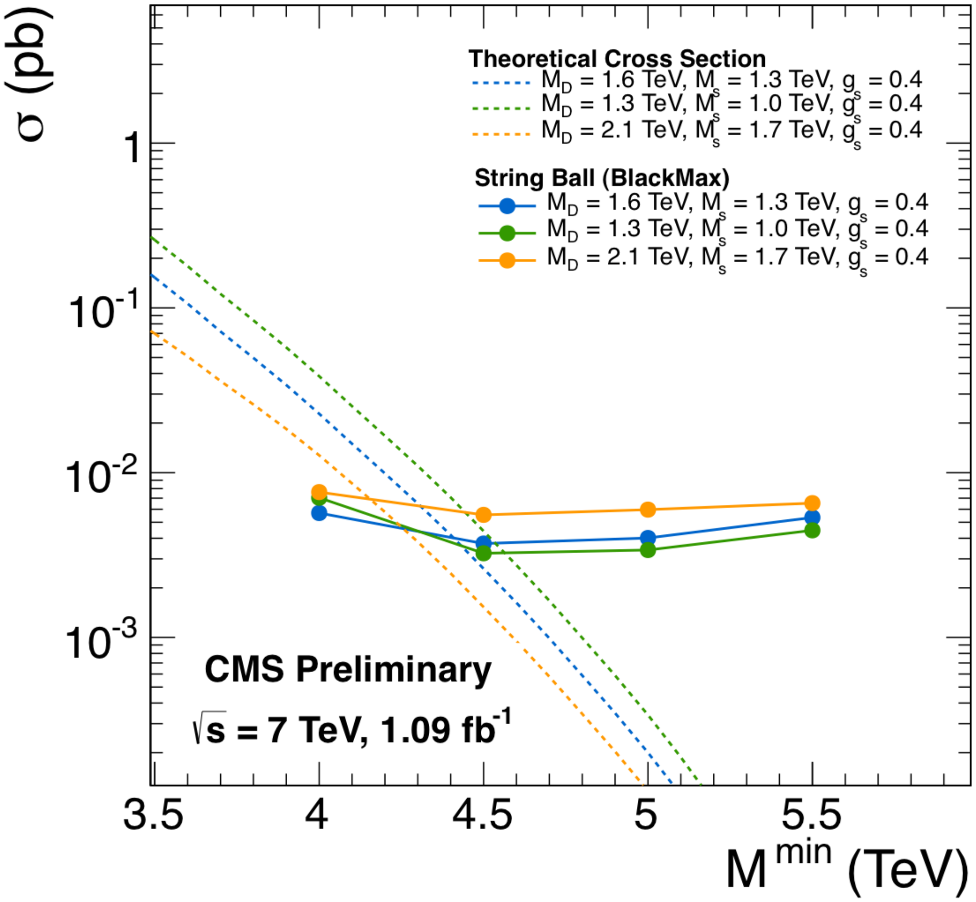
CMS √s = 7 TeV, 4.7 fb-1
a)
Multiplicity, N ≥ 3
Observed
Expected ± 1σ
Expected ± 2σ
Observed, 2010 data
Expected, 2010 data
2010, 35 pb-1
2011, 4.7 fb-1
σ(ST > STmin) × A (pb)
10
1
10-1
10-2
10-3
2000
3000
4000
5000
STmin (GeV)

Black holes

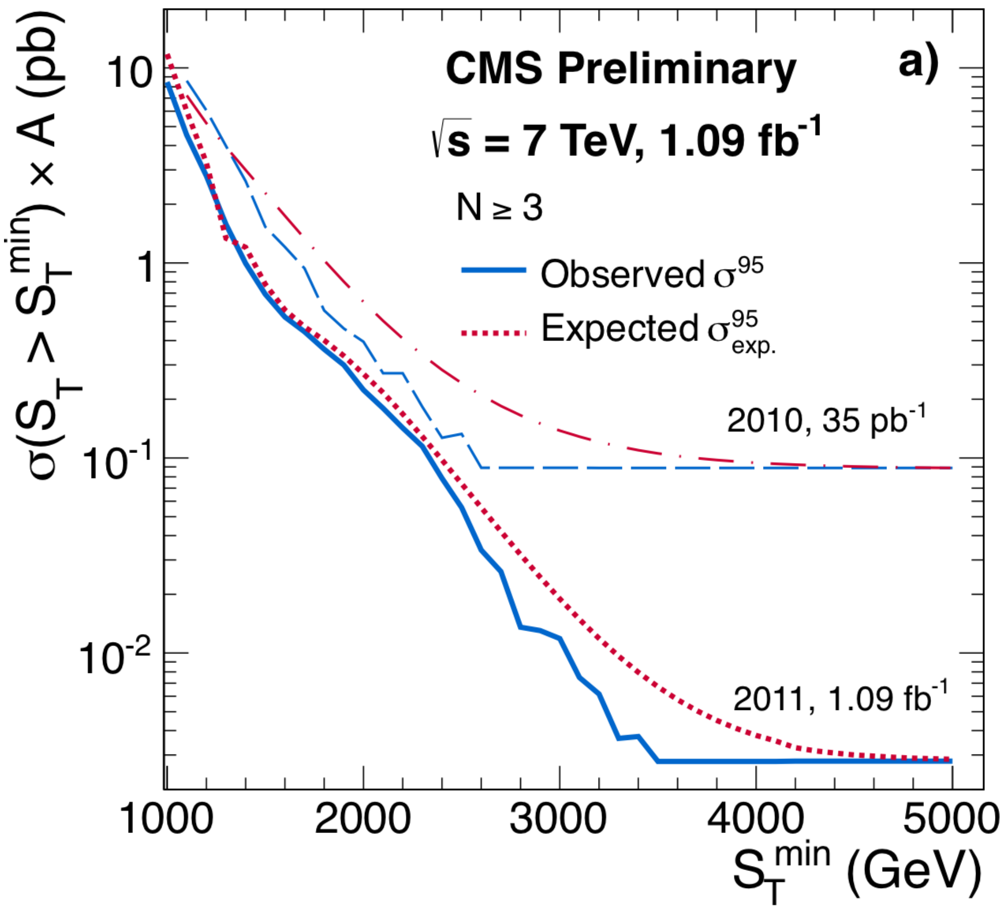


CMS √s = 7 TeV, 4.7 fb-1
b)
Multiplicity, N ≥ 4
Observed
Expected ± 1σ
Expected ± 2σ
Observed, 2010 data
Expected, 2010 data
2010, 35 pb-1
2011, 4.7 fb-1
σ(ST > ST min) × A (pb)
ST min (GeV)
10
1
10-1
10-2
10-3
2000
3000
4000
5000

Black holes

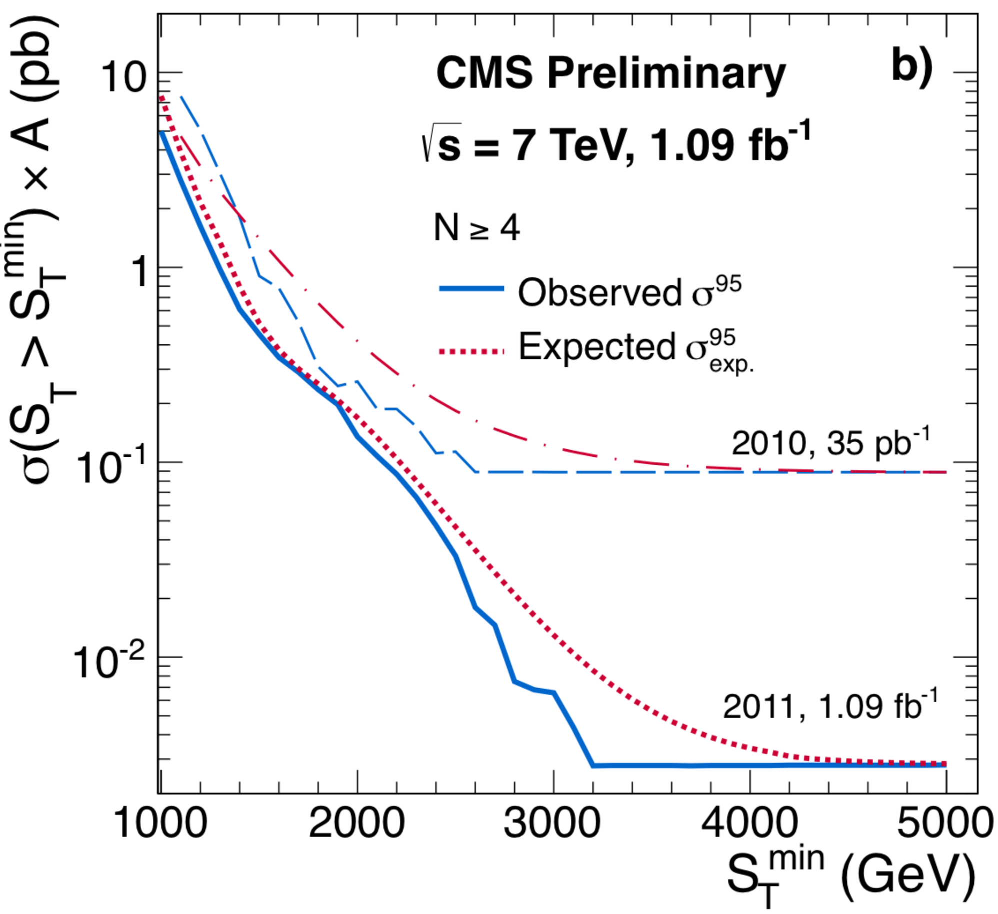

σ (pb)
1
10-1
10-2
10-3
Theoretical Cross Section
MD = 1.6 TeV, Ms = 1.3 TeV, gs = 0.4
MD = 1.3 TeV, Ms = 1.0 TeV, gs = 0.4
MD = 2.1 TeV, Ms = 1.7 TeV, gs = 0.4
String Ball (BlackMax)
MD = 1.6 TeV, Ms = 1.3 TeV, gs = 0.4
MD = 1.3 TeV, Ms = 1.0 TeV, gs = 0.4
MD = 2.1 TeV, Ms = 1.7 TeV, gs = 0.4
CMS Preliminary
√s = 7 TeV, 1.09 fb-1
3.5
4
4.5
5
5.5
M min (TeV)

Black holes



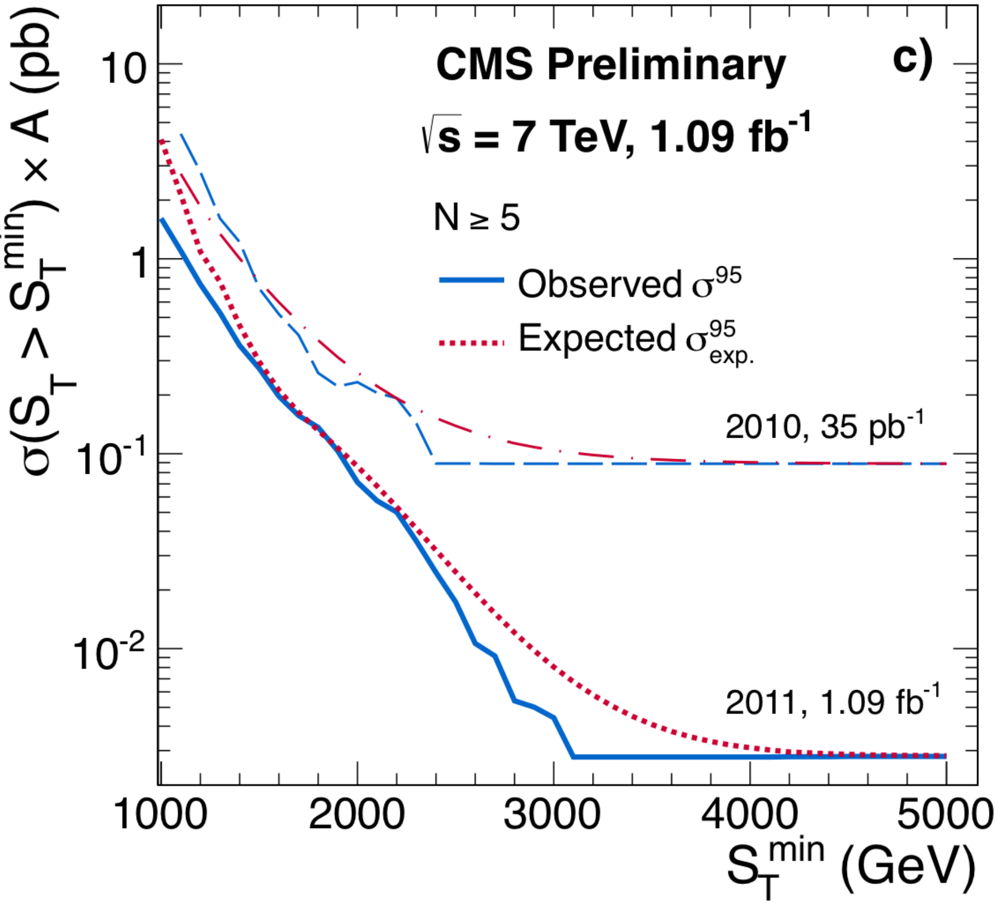
CMS Preliminary
a)
$\sqrt{s}$ = 7 TeV, 1.09 fb^{-1}
N ≥ 3
Observed σ^{95}
Expected $\sigma^{95}_{exp.}$
2010, 35 pb^{-1}
2011, 1.09 fb^{-1}
$\sigma(S_T > S_T^{min}) \times A$ (pb)
10
1
10^{-1}
10^{-2}
1000
2000
3000
4000
5000
S_T^{min} (GeV)

Black holes



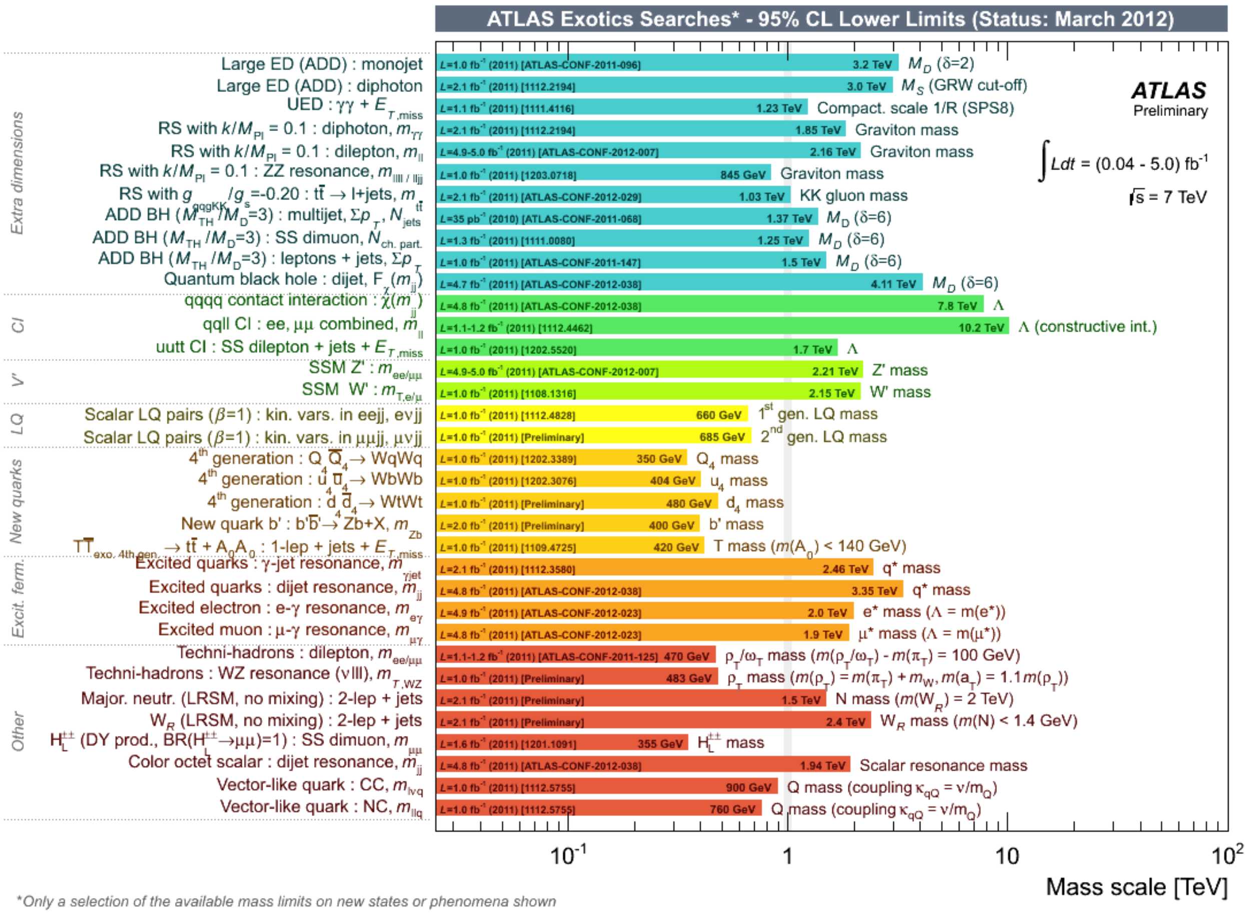
CMS Preliminary
b)
$\sqrt{s}$ = 7 TeV, 1.09 fb^{-1}
N ≥ 4
Observed σ^{95}
Expected $\sigma^{95}_{exp.}$
2010, 35 pb^{-1}
2011, 1.09 fb^{-1}
10
1
10^{-1}
10^{-2}
1000
2000
3000
4000
5000
S_T^{min} (GeV)
$\sigma(S_T > S_T^{min}) \times A$ (pb)

Black holes



CMS Preliminary
c)
$\sqrt{s}$ = 7 TeV, 1.09 fb^{-1}
N ≥ 5
Observed σ^{95}
Expected $\sigma^{95}_{exp.}$
2010, 35 pb^{-1}
2011, 1.09 fb^{-1}
$\sigma(S_T > S_T^{min}) \times A$ (pb)
10
1
10^{-1}
10^{-2}
1000
2000
3000
4000
5000
S_T^{min} (GeV)

ATLAS exotica summary plot



Conclusions

- ✓ CMS & ATLAS have significant discovery potential
- ✓ LHC will be able to discover Higgs boson and to check its basic properties
- ✓ LHC will be able to discover SUSY with squark and gluino masses up to 2.5 TeV.

There is nonzero probability to find something beyond SM or MSSM(extra dimensions, Z'-boson, compositeness ...)

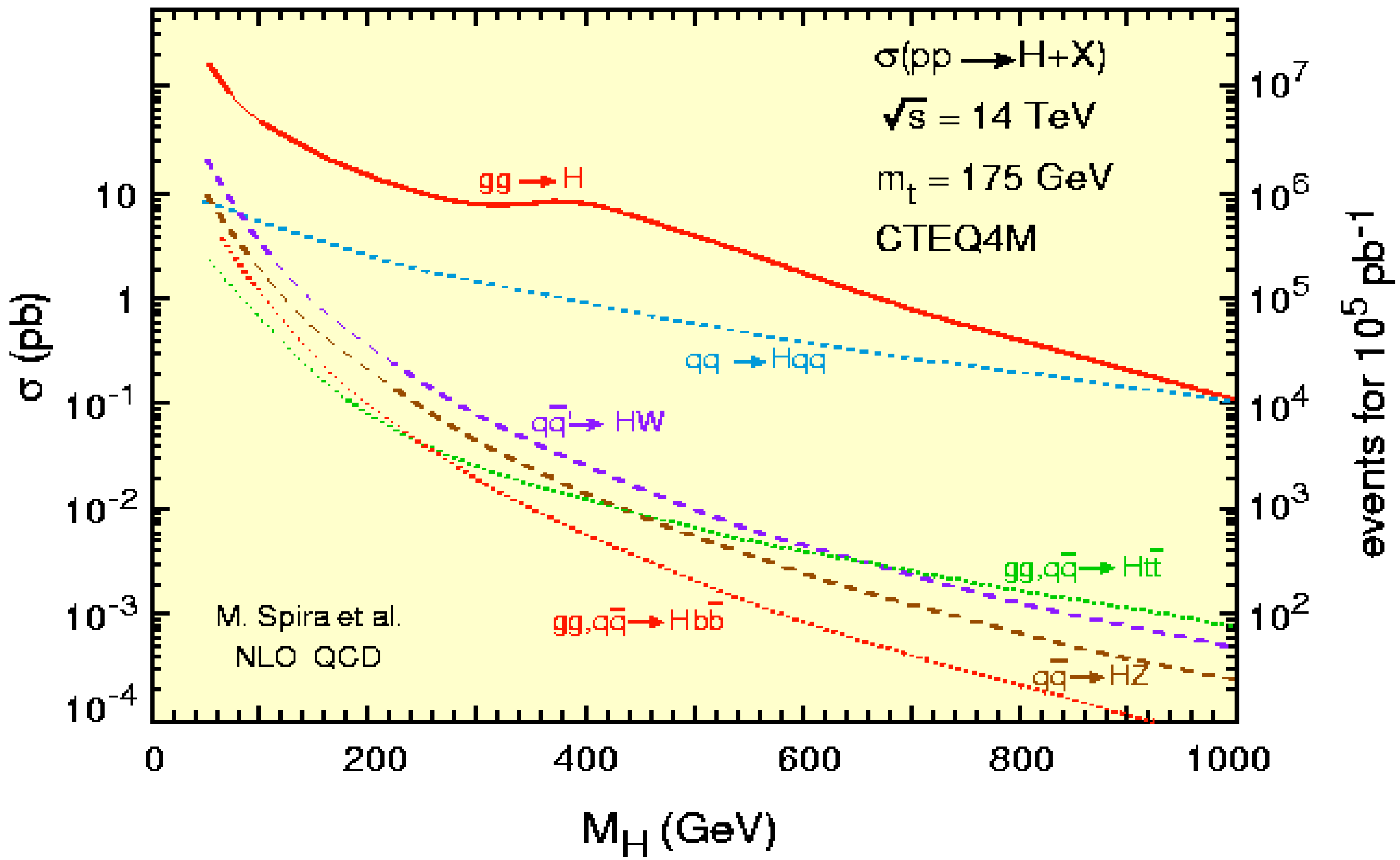
- ✓ Heavy gauge bosons up to ~5-6 TeV
- ✓ Heavy neutrino up to 2.6 TeV
- ✓ RS model ED up to ~4 TeV

Conclusions

- At any rate after LHC we will know the mechanism of electroweak symmetry breaking (Higgs boson or something more exotic?) and the basic properties of the matter structure at TeV scale.

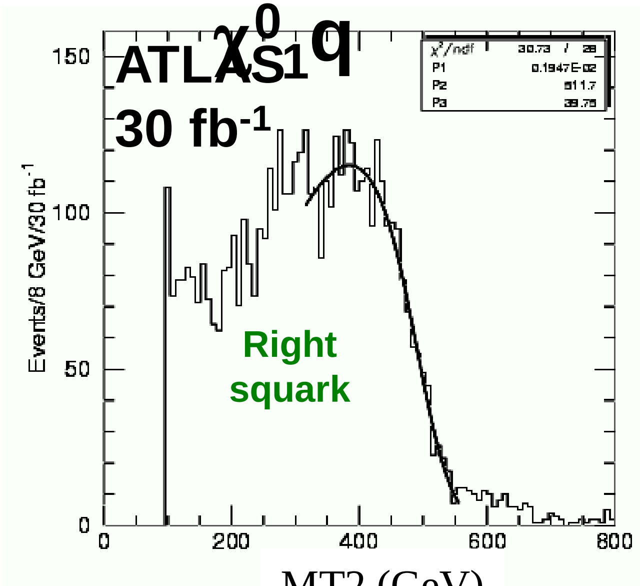
Backup slides

Higgs boson production cross section at the LHC



Other mass measurements

$\tilde{q}_R \to \chi^0_1 q$

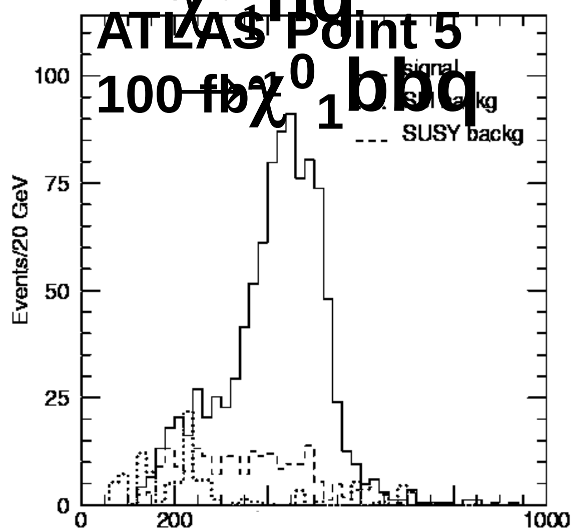


2 hard jets and lots of E_T^{miss}. Reconstruct with

$$M_{T2}^2 = \min_{\not p_1+\not p_2=\not p_T}\left[\max\left\{m_T^2(p_T^{\ell_1},\not p_1), m_T^2(p_T^{\ell_2},\not p_2)\right\}\right]$$

$m(q_R)-m(\chi^0_1) = (424.2 \pm 10.9)$ GeV

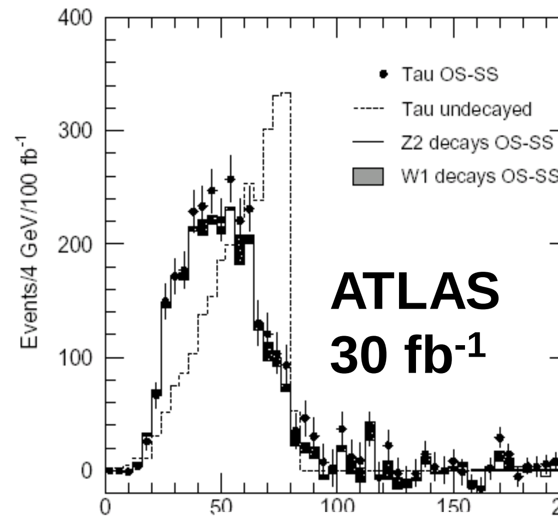
$\tilde{q}_L \to \chi^0_2 q \to \chi^0_1 hq \to \chi^0_1 bbq$



Two body decay of χ^0_2 to higgs and χ^0_1.

Reconstruct higgs mass (2 b-jets) and

$\chi^o_2 \to \tilde{\tau}\tau \to \chi^0_1 \tau\tau$



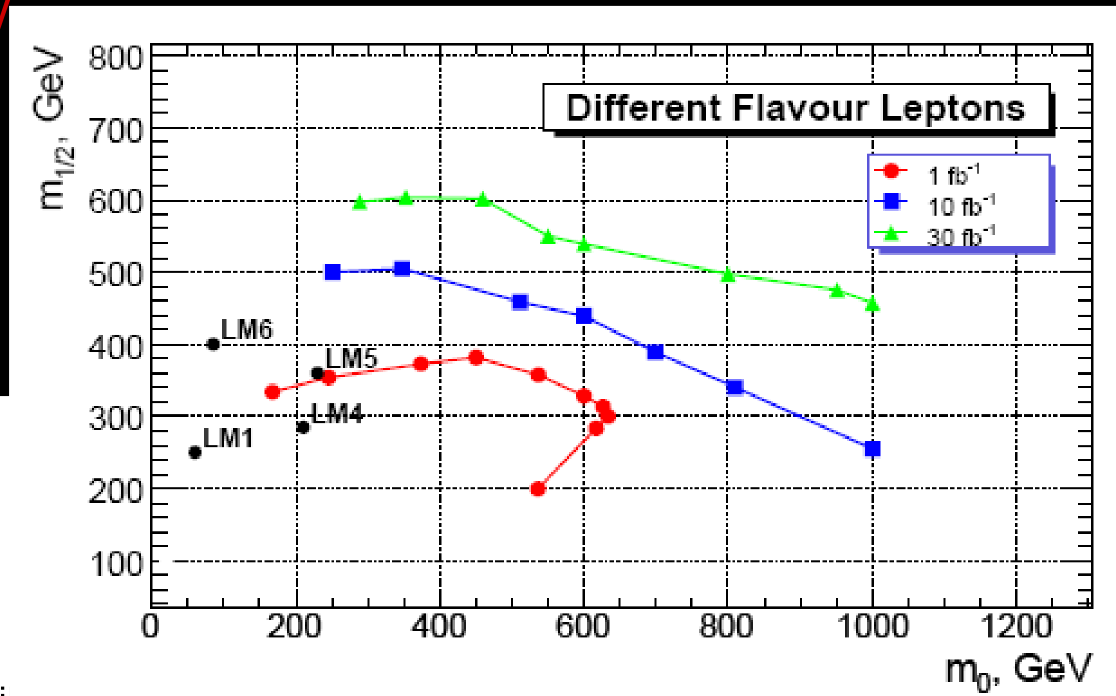
Tau decay dominates neutralino BR at large tanβ.

No sharp edge because of ν, but end-point can still be measured.

Using the $e^{\pm}m^{-}+E^{T}_{miss}$ signature in the search for Supersymmetry and lepton flavour violation in neutralino decay

A search was performed using the CMS detector simulation. The optimal cut set was found to be:

- Isolated leptons with $p_t > 20$ GeV
- EtMiss > 300 GeV



[redacted]

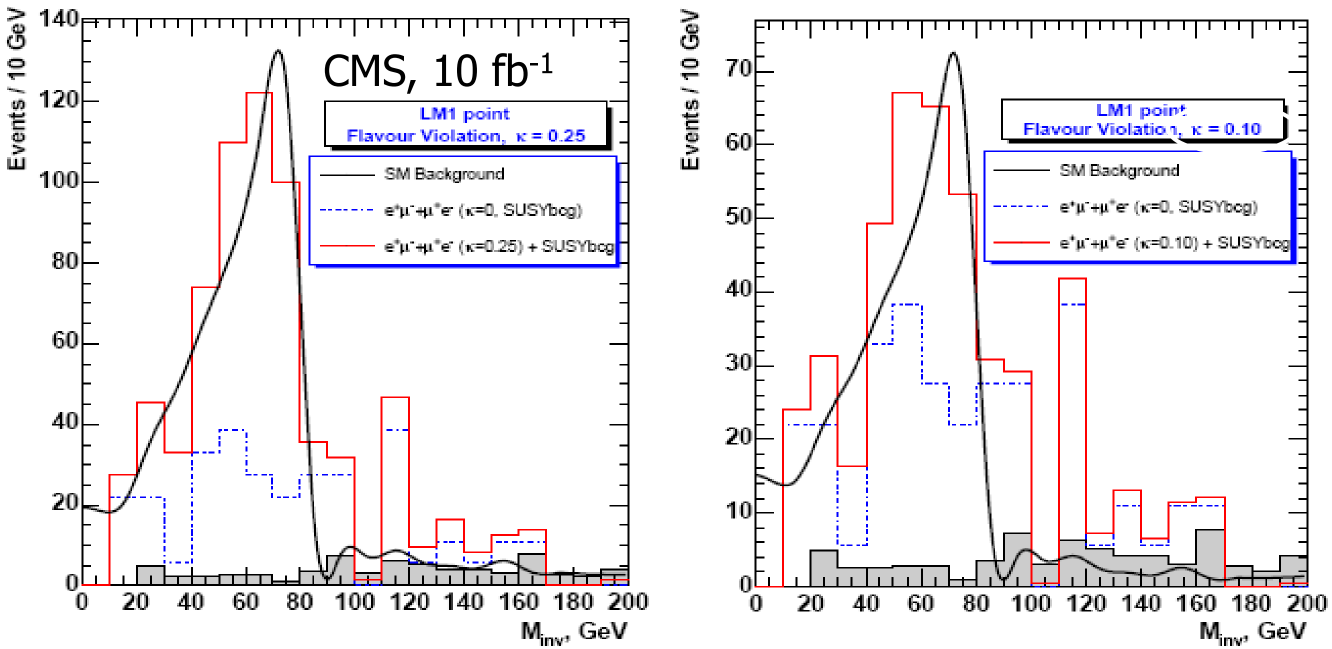
$$\mathrm{BR}(\ell_i \ell_j) \equiv \mathrm{BR}(\tilde{\chi}_2^0 \to \ell_i \ell_j \tilde{\chi}_1^0).$$

[redacted]

$$\kappa = 2x \sin^2\theta \cos^2\theta,$$

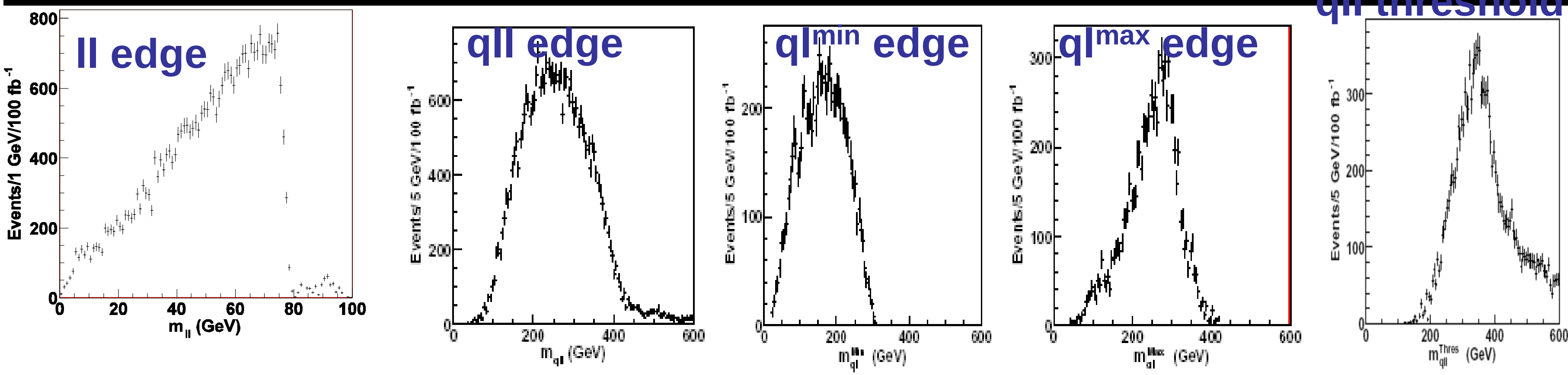
[redacted]

$$x = \frac{\Delta m^2_{\tilde{e}\tilde{\mu}}}{\Delta m^2_{\tilde{e}\tilde{\mu}} + \Gamma^2},$$



Moscow

SUSY (s)lepton flavour studies with ATLAS



Gjelsten, Lytken, Miller, Osland, Polesello,ATL-PHYS-2004-007

SPS1a (bulk region)
m_0= 100 GeV,
$m_{1/2}$= 250 GeV,
A_0= -100 GeV,
$\tan(\beta)$=10 , μ>0

Expected errors on the masses

$\Delta m(\chi_1^0)$= 4.8 GeV, $\Delta m(\chi_2^0)$= 4.7 GeV,
$\Delta m(l_R)$ = 4.8 GeV, $\Delta m(q_L)$= 8.7 GeV

5 relations
4 masses