Will Your Favorite SUSY Point Be Visible at LHC7?

Andre Lessa

Homer L. Dodge Department of Physics and Astronomy
University of Oklahoma

West Coast LHC Theory Network - May 21st, 2010

- **H. Baer, V. Barger, A. Lessa and X. Tata**, JHEP 0909:063,2009.
- **H. Baer, V. Barger, A. Lessa and X. Tata**, arXiv:1004.3594.

Outline

- Introduction
- Search Strategies for LHC7
- Upper Reach
- mSUGRA Reach
- Non mSUGRA Models
- Conclusions

Why We Like SUSY

Why We Like SUSY

- Maximal space-time symmetry in 4D

Why We Like SUSY

- Maximal space-time symmetry in 4D
- Stabilizes the EW scale

Why We Like SUSY

- Maximal space-time symmetry in 4D
- Stabilizes the EW scale
- Respects the EW precision contraints

Why We Like SUSY

- Maximal space-time symmetry in 4D
- Stabilizes the EW scale
- Respects the EW precision contraints
- Provides a dark matter candidate, light Higgs and gauge unification

Why We Like SUSY

- Maximal space-time symmetry in 4D
- Stabilizes the EW scale
- Respects the EW precision contraints
- Provides a dark matter candidate, light Higgs and gauge unification
- Several models and interesting physics...

Why We Like SUSY

- Maximal space-time symmetry in 4D
- Stabilizes the EW scale
- Respects the EW precision contraints
- Provides a dark matter candidate, light Higgs and gauge unification
- Several models and interesting physics...

...However it has over 100 parameters just in the MINIMAL (unconstrained) case!

Search Strategies for LHC7

- Each model (or class of models) has distinct signatures and backgrounds

Search Strategies for LHC7

- Each model (or class of models) has distinct signatures and Backgrounds
- General Approach:

Search Strategies for LHC7

- Each model (or class of models) has distinct signatures and backgrounds
- General Approach:

- Look for regions in phase space where:
  - $S \geq$ few events
  - $S/BG >$ confidence threshold
  - $S > n\sigma\sqrt{BG}$

Search Strategies for LHC7

- Each model (or class of models) has distinct signatures and backgrounds
- General Approach:

- Look for regions in phase space where:
  - $S \geq$ few events
  - $S/BG >$ confidence threshold
  - $S > n\sigma\sqrt{BG}$
- For the results presented here:
  - few events $= 5$
  - confidence threshold $= 20$ %
  - n $= 5$ (5 sigma discovery)

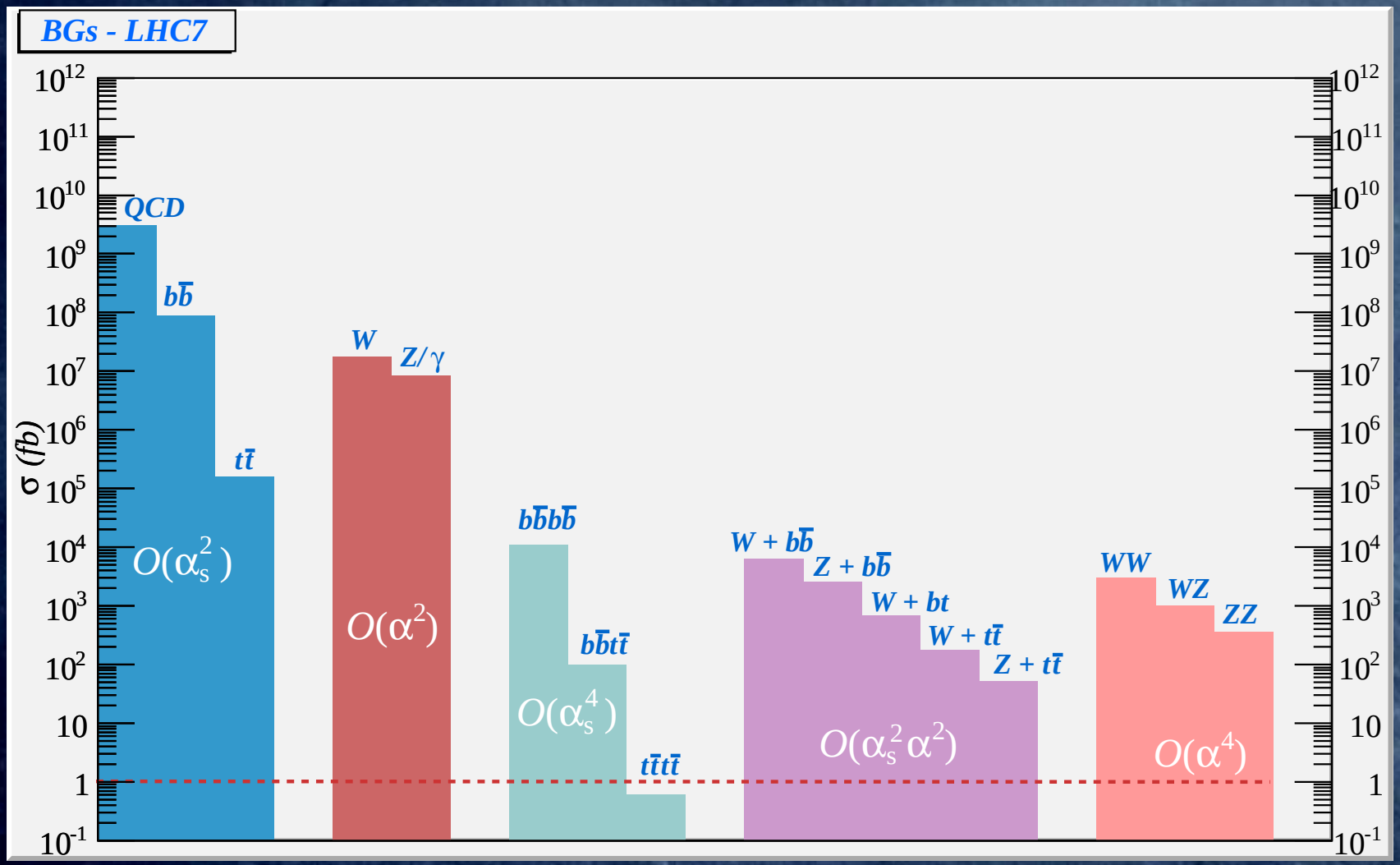
Search Strategies for LHC7

- Each model (or class of models) has distinct signatures and backgrounds
- General Approach:

- Look for regions in phase space where:
  - $S \geq$ few events
  - $S/BG >$ confidence threshold
  - $S > n\sigma\sqrt{BG}$
- Standard SUSY channels:
  - $\not{E}_T$ + jets
  - OS, SS dileptons + jets
  - Trilepton
  - jets + γ, ...

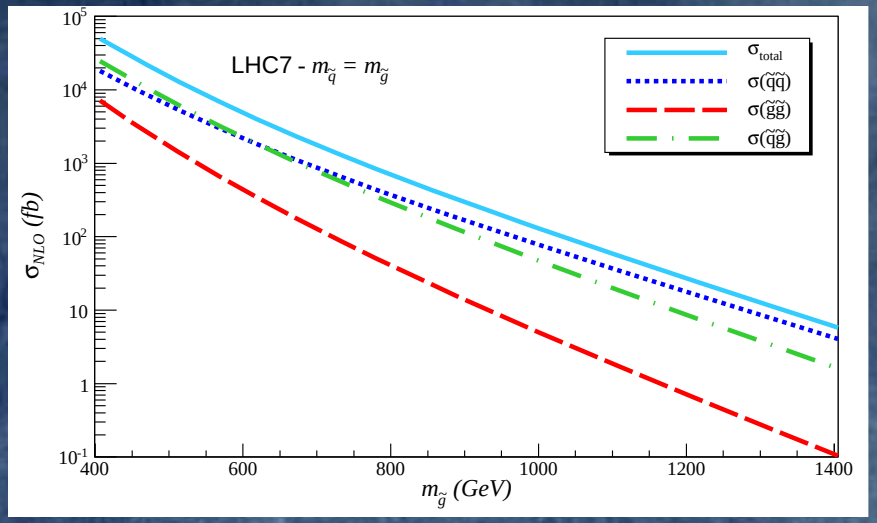
- For the results presented here:
  - few events $= 5$
  - confidence threshold $= 20$ %
  - n $= 5$ (5 sigma discovery)

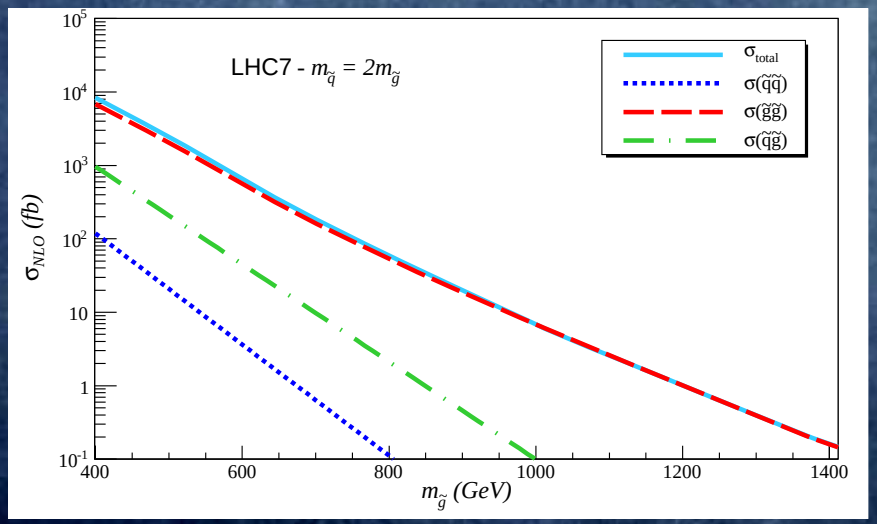
SM Backgrounds



SUSY Signal

- For LHC7 we can focus on strong cross-sections





Upper Reach

- Some rough guides:

Upper Reach

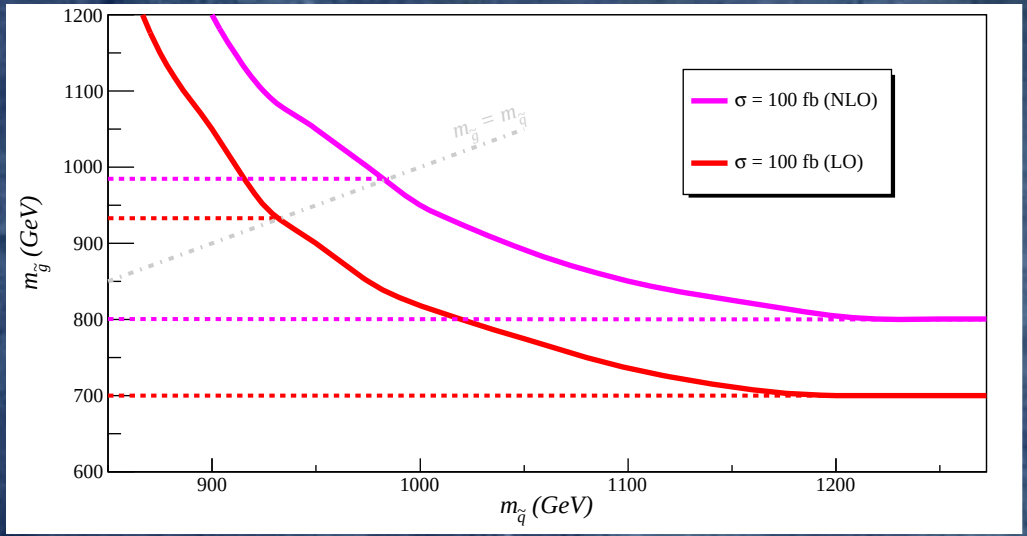
- Some rough guides:
  - Small luminosity $\rightarrow$ signal needs to be produced strongly ($\tilde{g}/\tilde{q}$)

Upper Reach

- Some rough guides:
  - Small luminosity $\rightarrow$ signal needs to be produced strongly ($\tilde{g}/\tilde{q}$)
  - Require at least 100 SUSY events within 1 fb^{-1} of data

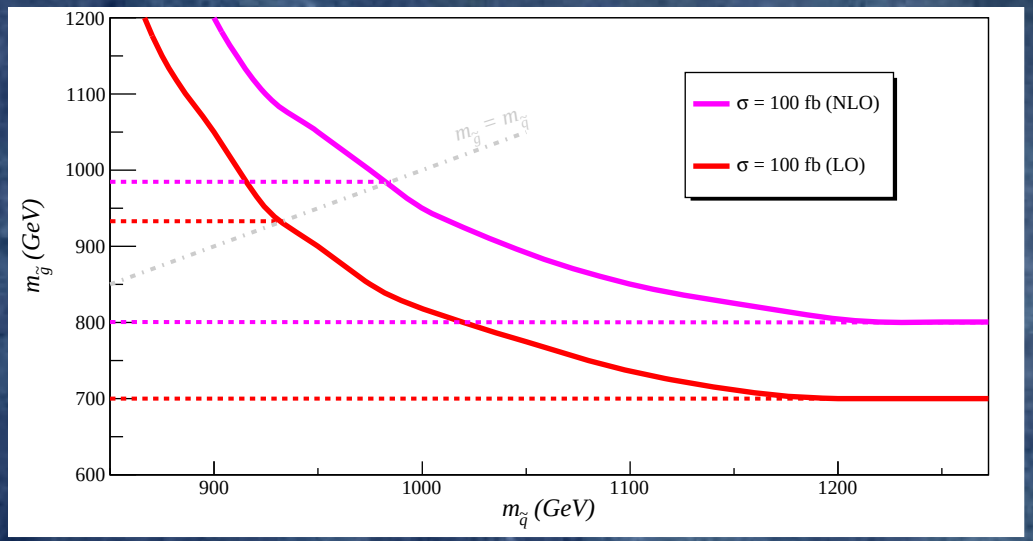
Upper Reach

- Some rough guides:
  - Small luminosity $\rightarrow$ signal needs to be produced strongly ($\tilde{g}/\tilde{q}$)
  - Require at least 100 SUSY events within 1 fb^{-1} of data



Upper Reach

- Some rough guides:
  - Small luminosity $\rightarrow$ signal needs to be produced strongly ($\tilde{g}/\tilde{q}$)
  - Require at least 100 SUSY events within 1 fb^{-1} of data



$$0.7 \pm 0.1 \text{ TeV} \lesssim m_{\tilde{g}} \lesssim 0.9 \pm 0.1 \text{ TeV}$$

mSUGRA

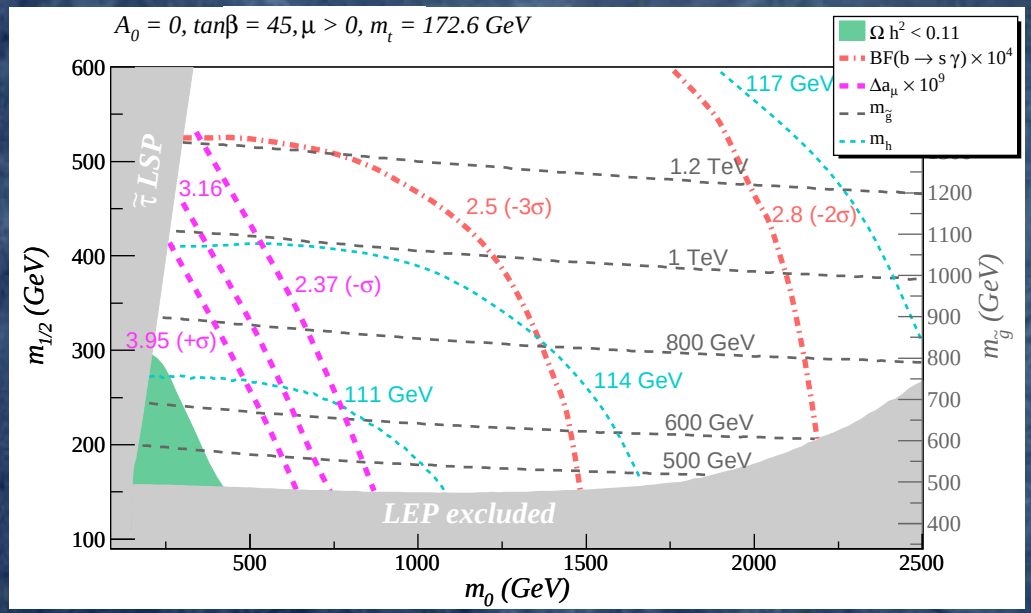
- For a more detailed analysis we need a specific model (or class of models).

mSUGRA

- For a more detailed analysis we need a specific model (or class of models).
- mSUGRA: $m_0, m_{1/2}, A_0, \tan\beta, sgn(\mu)$
  with $A_0 = 0,\ \mu > 0,\ \tan\beta = 45$

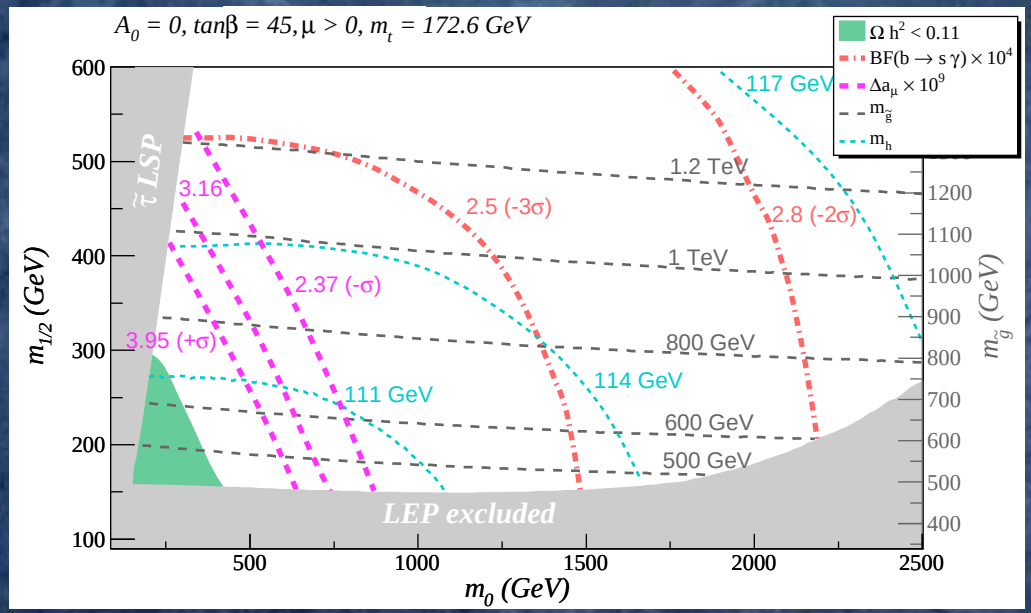
mSUGRA

- For a more detailed analysis we need a specific model (or class of models).
- mSUGRA: $m_0, m_{1/2}, A_0, \tan\beta, sgn(\mu)$
  with $A_0 = 0,\ \mu > 0,\ \tan\beta = 45$
- Some observables:



mSUGRA

- For a more detailed analysis we need a specific model (or class of models).
- mSUGRA: $m_0, m_{1/2}, A_0, \tan\beta, sgn(\mu)$
  with $A_0 = 0,\ \mu > 0,\ \tan\beta = 45$
- Some observables:



→ Should not be taken too seriously, since mSUGRA is just a "prototype" model

Simulation Details

- **Background Simulation:** AlpGen (MLM matching) + Pythia

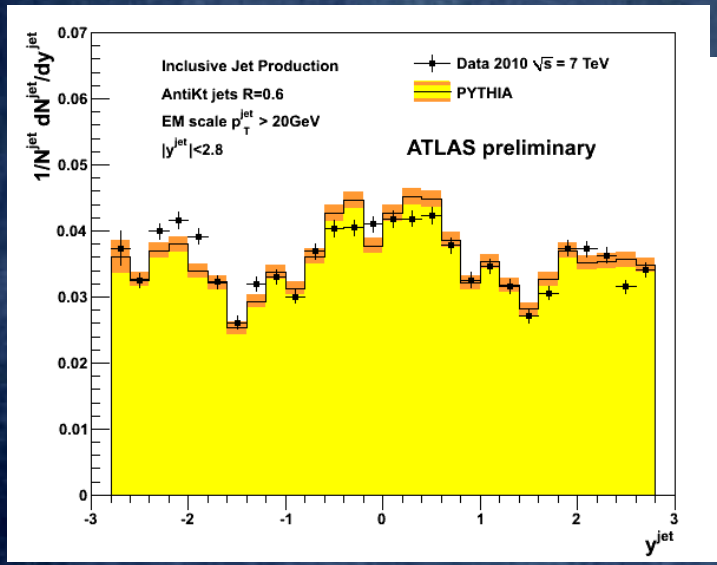
SM process	Cross section	number of events
QCD: 2, 3 and 4 jets	3.0×10^9 fb	26M
$t\bar{t}$: $t\bar{t}$ + 0, 1 and 2 jets	1.6×10^5 fb	5M
$b\bar{b}$: $b\bar{b}$ + 0, 1 and 2 jets	8.8×10^7 fb	91M
Z + jets: $Z/\gamma(\rightarrow l\bar{l}, \nu\bar{\nu})$ + 0, 1, 2 and 3 jets	8.6×10^6 fb	13M
W + jets: $W^{\pm}(\rightarrow l\nu)$ + 0, 1, 2 and 3 jets	1.8×10^7 fb	19M
$Z + t\bar{t}$: $Z/\gamma(\rightarrow l\bar{l}, \nu\bar{\nu}) + t\bar{t}$ + 0, 1 and 2 jets	53 fb	0.6M
$Z + b\bar{b}$: $Z/\gamma(\rightarrow l\bar{l}, \nu\bar{\nu}) + b\bar{b}$ + 0, 1 and 2 jets	2.6×10^3 fb	0.3M
$W + b\bar{b}$: $W^{\pm}(\rightarrow l\nu) + b\bar{b}$ + 0, 1 and 2 jets	6.4×10^3 fb	9M
$W + t\bar{t}$: $W^{\pm}(\rightarrow l\nu) + t\bar{t}$ + 0, 1 and 2 jets	1.8×10^2 fb	9M
$W + tb$: $W^{\pm}(\rightarrow l\nu) + \bar{t}b(t\bar{b})$	6.8×10^2 fb	0.025M
$t\bar{t}t\bar{t}$	0.6 fb	1M
$t\bar{t}b\bar{b}$	1.0×10^2 fb	0.2M
$b\bar{b}b\bar{b}$	1.1×10^4 fb	0.07M
WW: $W^{\pm}(\rightarrow l\nu) + W^{\pm}(\rightarrow l\nu)$	3.0×10^3 fb	0.005M
WZ: $W^{\pm}(\rightarrow l\nu) + Z(\rightarrow all)$	3.4×10^3 fb	0.009M
ZZ: $Z(\rightarrow all) + Z(\rightarrow all)$	4.0×10^3 fb	0.02M

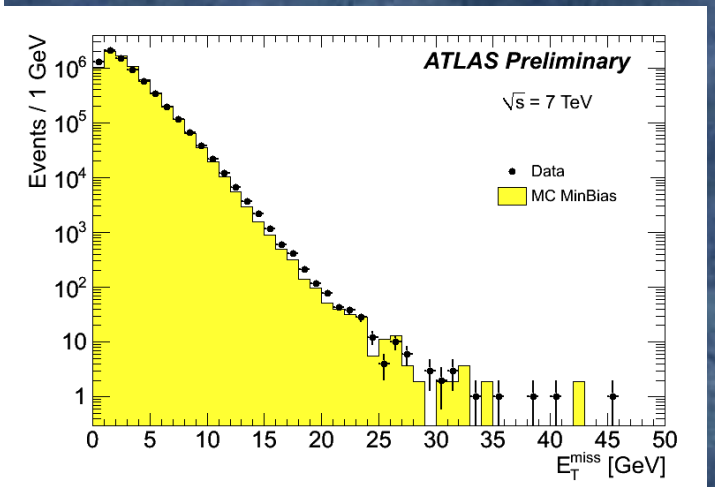
Simulation Details

- Signal Simulation:
  - Isajet 7.79 (all $2 \rightarrow 2$ susy processes)
- Detector Simulation:
  - Toy detector with
    - Energy smearing
    - b-tag efficiency (60 %) and mistagging
    - Cone jet algorithm
- Luminosity:
  - $\gtrsim 1$ fb^{-1} for BG (except QCD)
  - $\gtrsim 2$ fb^{-1} for Signal

Search Channels

- Early data results show excellent detector/MC agreement!



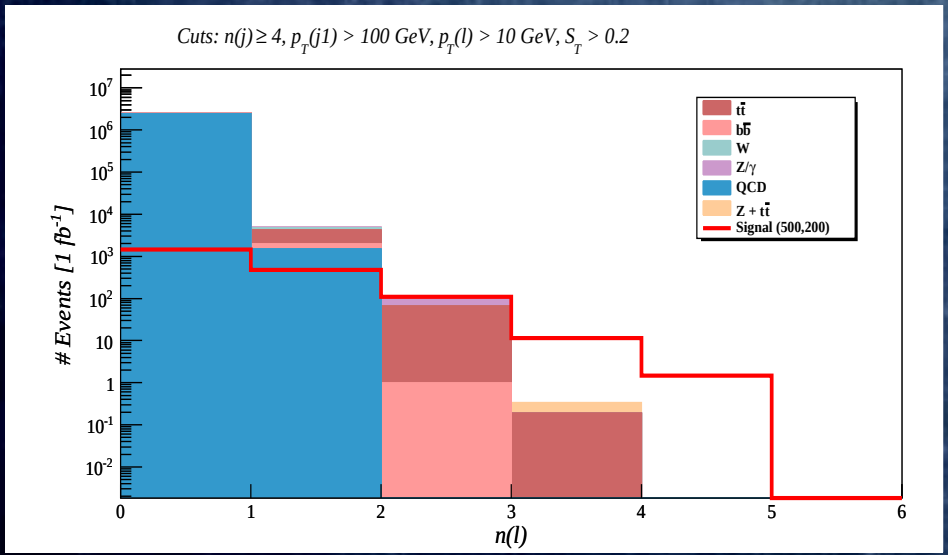


- $\not{E}_T$, b-tagging, lepton ID should be available for early analysis!

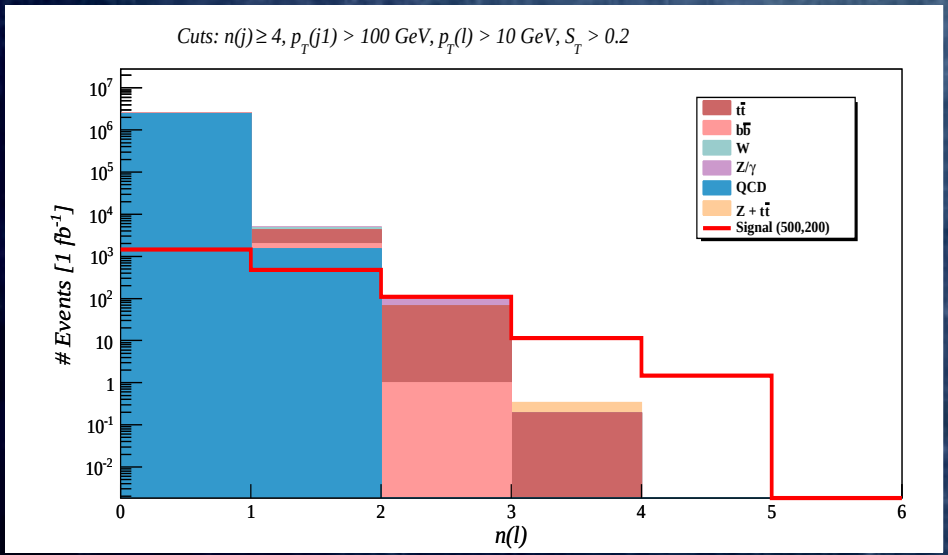
- But...
  - $\not{E}_T$ has just been measured at low E_T events
  - Fake $\not{E}_T$ grows with $\sum E_T$
  - SUSY searches usually require $\not{E}_T \sim 100 - 500$ GeV

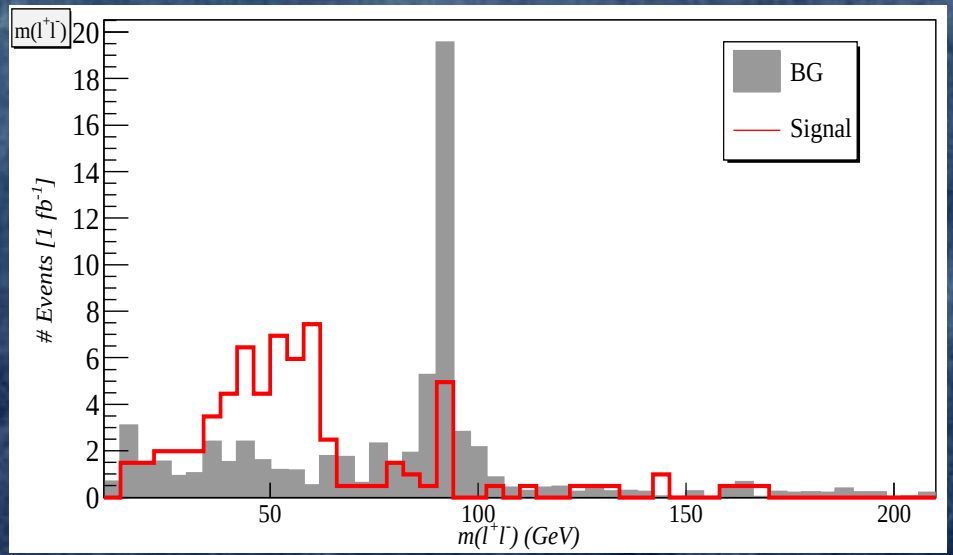
- But...
  - $\not{E}_T$ has just been measured at low E_T events
  - Fake $\not{E}_T$ grows with $\sum E_T$
  - SUSY searches usually require $\not{E}_T \sim 100 - 500$ GeV
- Just in case, what can be done without $\not{E}_T$?
  - Multi-μ channels (clean signal)
  - Dijet channel (α_{RTS})
  - Multi-lepton ($e + \mu$), if electron ID is reliable

- But...
  - $\not\!\!E_T$ has just been measured at low E_T events
  - Fake $\not\!\!E_T$ grows with $\sum E_T$
  - SUSY searches usually require $\not\!\!E_T \sim 100 - 500$ GeV
- Just in case, what can be done without $\not\!\!E_T$?
  - Multi-μ channels (clean signal)
  - Dijet channel (α_{RTS})
  - Multi-lepton ($e + \mu$), if electron ID is reliable

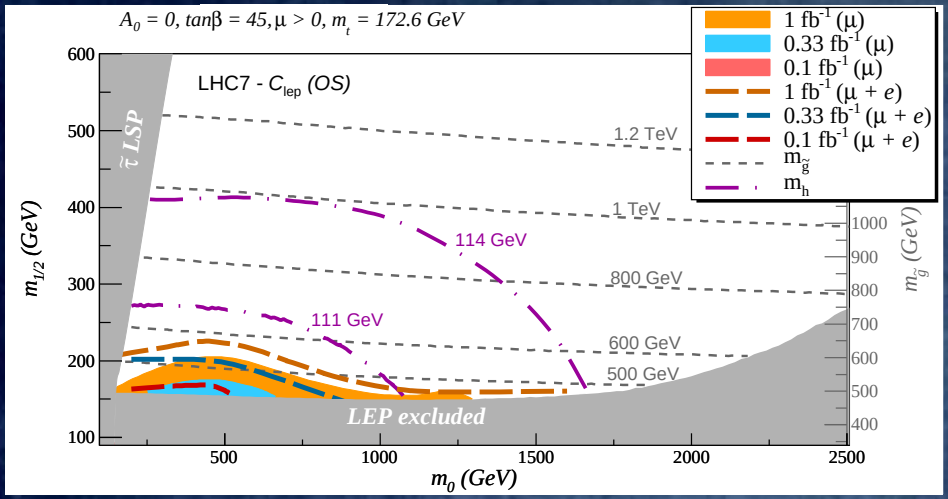


- But...
  - $\not\!\!E_T$ has just been measured at low E_T events
  - Fake $\not\!\!E_T$ grows with $\sum E_T$
  - SUSY searches usually require $\not\!\!E_T \sim 100 - 500$ GeV
- Just in case, what can be done without $\not\!\!E_T$?
  - Multi-μ channels (clean signal)
  - Dijet channel (α_{RTS})
  - Multi-lepton ($e + \mu$), if electron ID is reliable

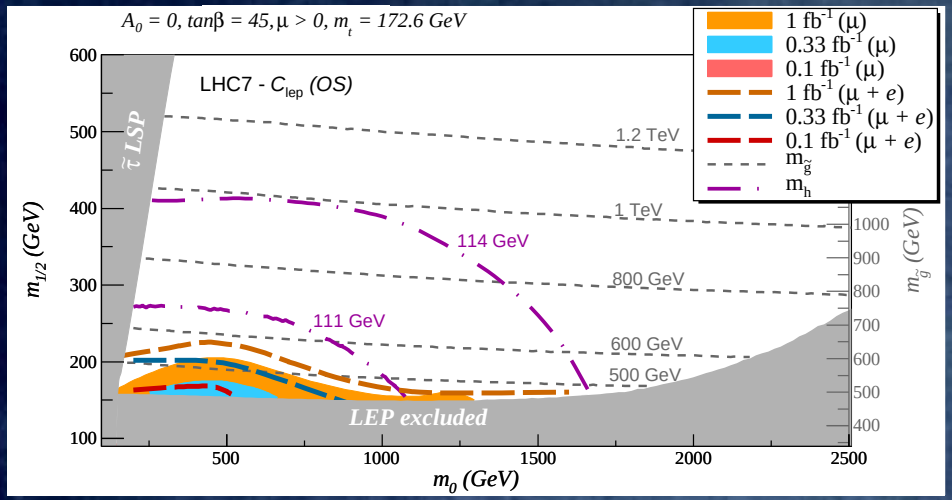


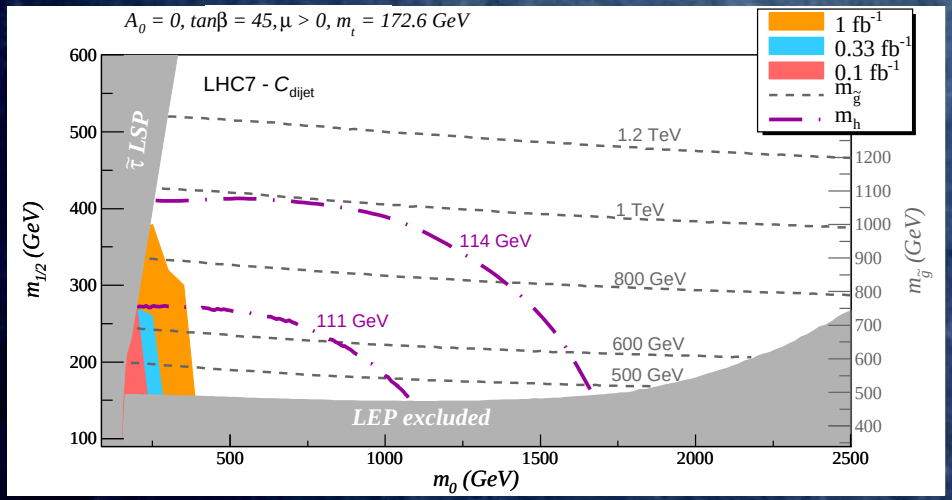


No-$\not{E}_T$ Reach

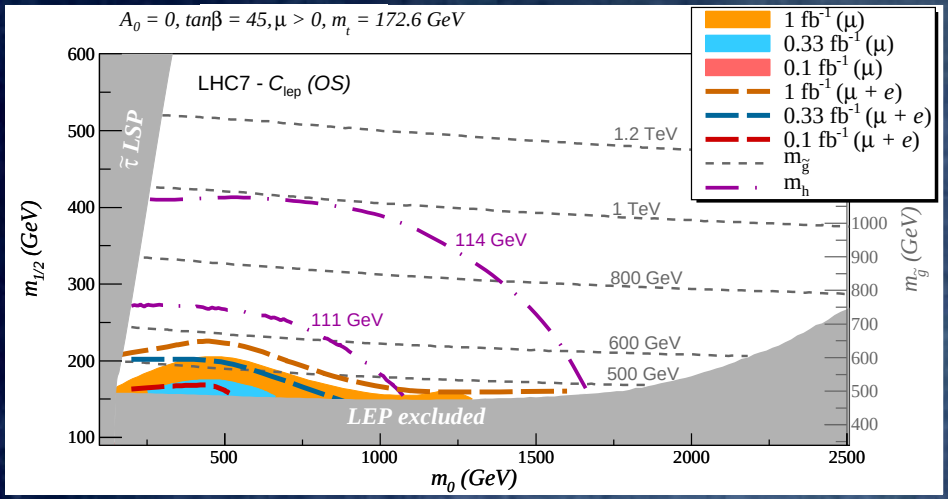


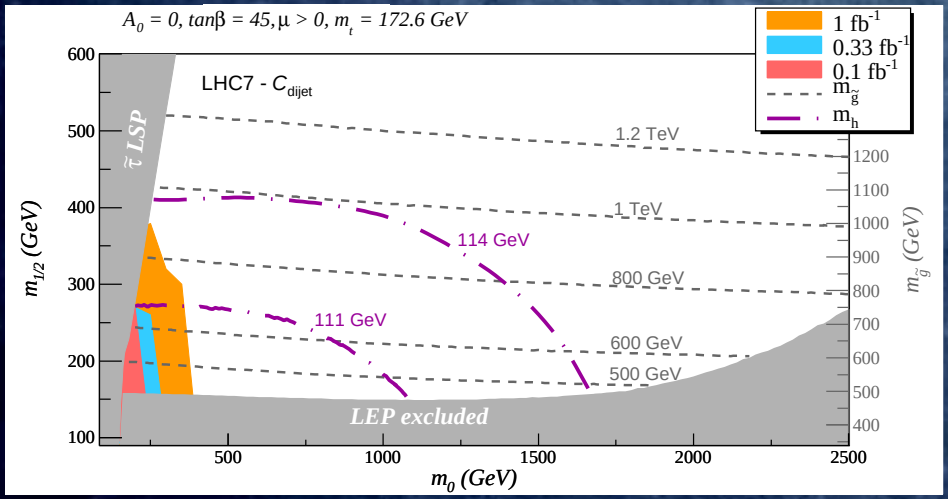
No-$\not{E}_T$ Reach





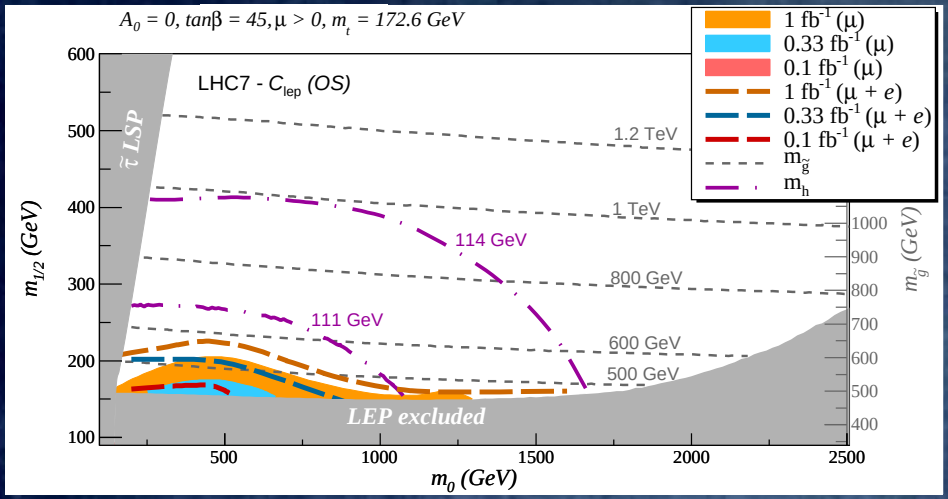
No-$\not{E}_T$ Reach

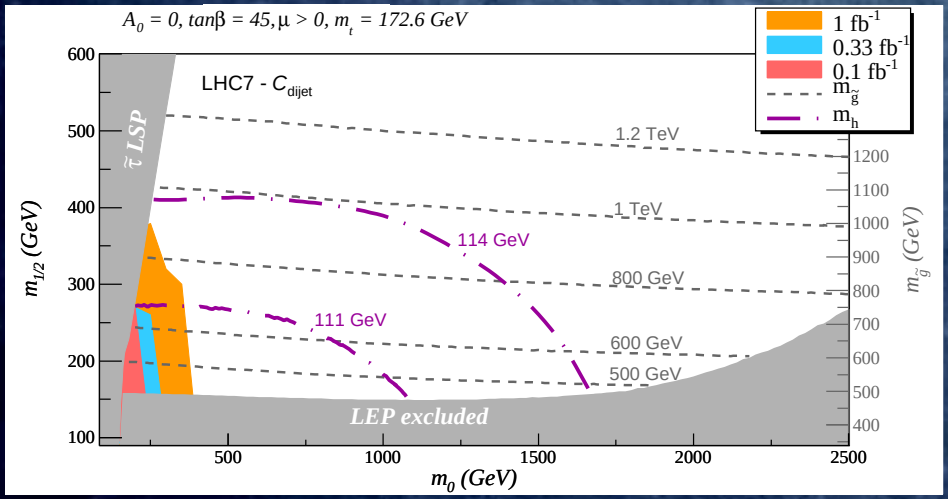




- At low m_0 ($m_{\tilde{q}} \sim m_{\tilde{g}}$)
  $\rightarrow$ dijet channel
- At "high" m_0 ($m_{\tilde{q}} \gtrsim m_{\tilde{g}}$)
  $\rightarrow$ OS/SF channel

No-$\not{E}_T$ Reach



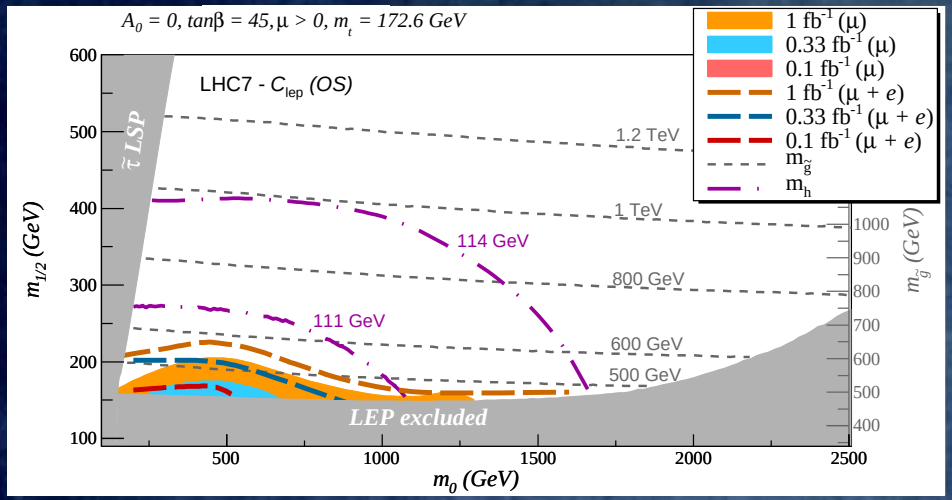


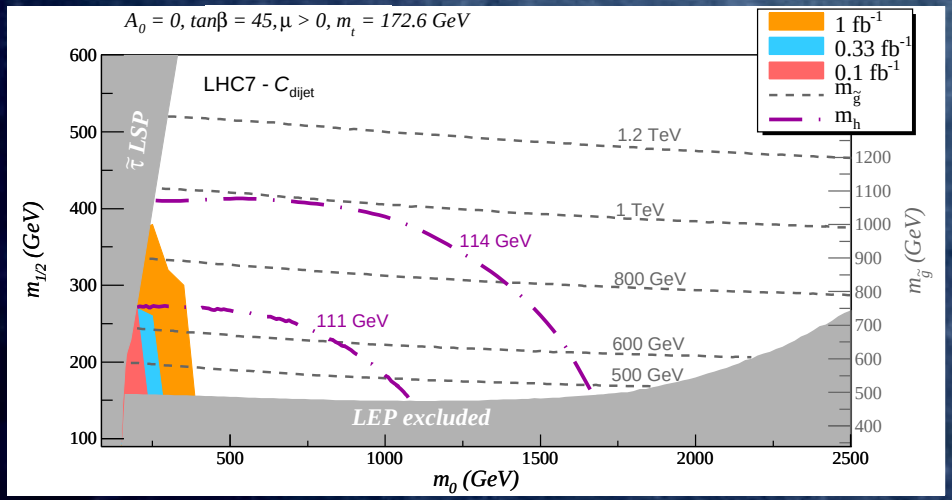
- At low m_0 ($m_{\tilde{q}} \sim m_{\tilde{g}}$)
  $\rightarrow$ dijet channel
- At "high" m_0 ($m_{\tilde{q}} \gtrsim m_{\tilde{g}}$)
  $\rightarrow$ OS/SF channel

for 0.33 fb^{-1}:

$$500 \text{ GeV} \lesssim m_{\tilde{g}} \lesssim 650 \text{ GeV}$$

No-$\not{E}_T$ Reach





- At low m_0 ($m_{\tilde{q}} \sim m_{\tilde{g}}$)
  $\rightarrow$ dijet channel
- At "high" m_0 ($m_{\tilde{q}} \gtrsim m_{\tilde{g}}$)
  $\rightarrow$ OS/SF channel

for 0.33 fb^{-1}:

$$500 \text{ GeV} \lesssim m_{\tilde{g}} \lesssim 650 \text{ GeV}$$

$\rightarrow$ Already competitive with Tevatron bounds!
($m_{\tilde{g}} \gtrsim 300 - 400$ GeV)

Search Channels

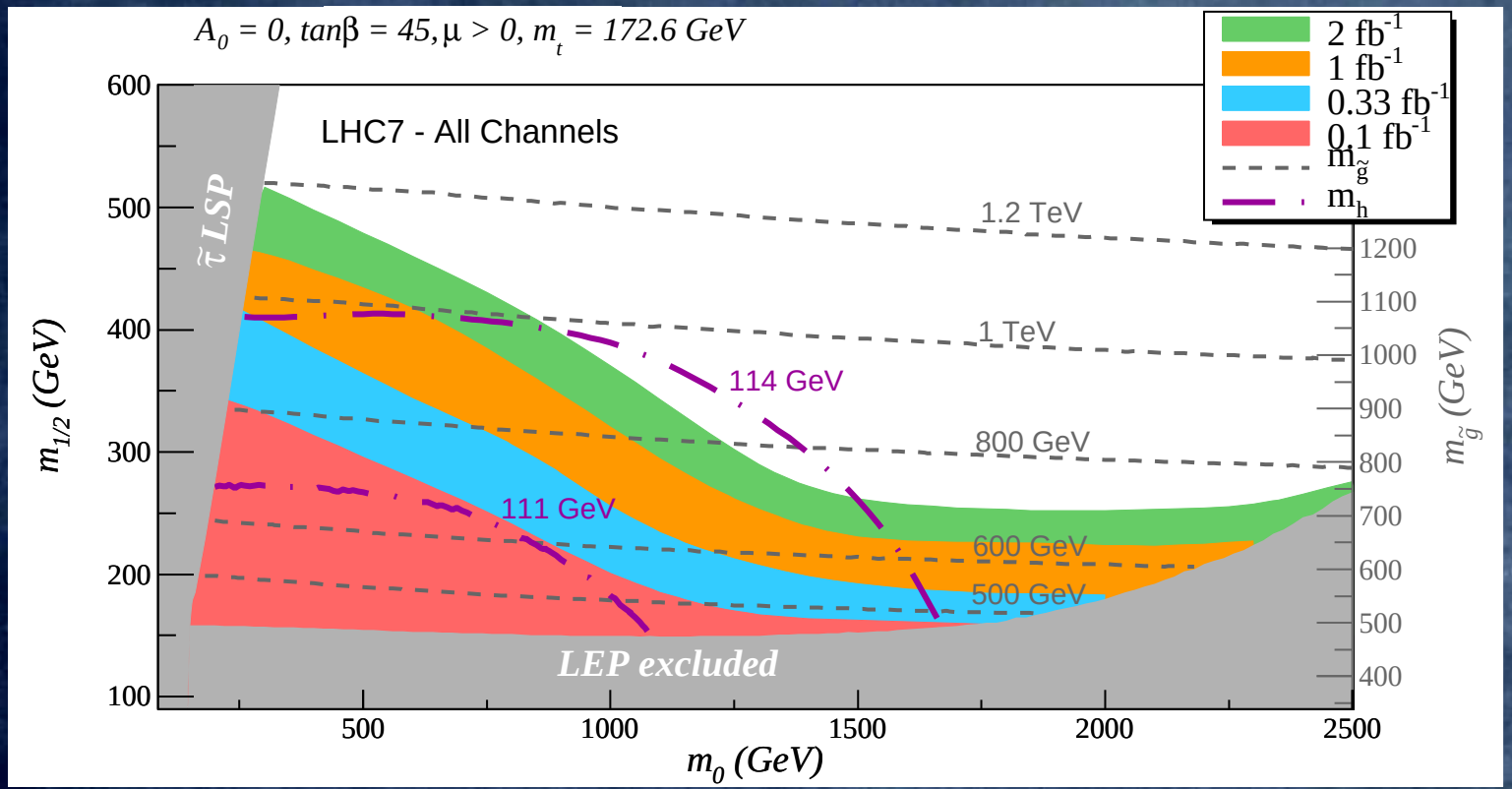
- Full Analysis (optimized search):
  - $\not{E}_T > 100$ - 1000 GeV
  - $n(jets) \geq 2$, 3, 4, 5 or 6
  - $n(b) \geq 0$, 1, 2 or 3
  - $E_T(j_1) > 50$ - 1000 GeV
  - $E_T(j_2) > 50$ - 500 GeV
  - $n(\ell) = 0$, 1, 2, 3, OS, SS and inclusive channel: $n(\ell) \geq 0$
  - 10 GeV$\leq m(\ell^+\ell^-) \leq 75$ GeV or $m(\ell^+\ell^-) \geq 105$ GeV
    (for the OS, same flavor (SF) dileptons only)
  - transverse sphericity $S_T > 0.2$

Search Channels

- Full Analysis (optimized search):
  - $\not{E}_T > 100$ - 1000 GeV
  - $n(jets) \geq 2$, 3, 4, 5 or 6
  - $n(b) \geq 0$, 1, 2 or 3
  - $E_T(j_1) > 50$ - 1000 GeV
  - $E_T(j_2) > 50$ - 500 GeV
  - $n(\ell) = 0$, 1, 2, 3, OS, SS and inclusive channel: $n(\ell) \geq 0$
  - 10 GeV$\leq m(\ell^+\ell^-) \leq 75$ GeV or $m(\ell^+\ell^-) \geq 105$ GeV
    (for the OS, same flavor (SF) dileptons only)
  - transverse sphericity $S_T > 0.2$
- Channel is chosen such that:
  - Signal is visible ($S \geq \max[5, 5\sigma\sqrt{BG}, 0.2BG]$)
  - Maximizes $S/\sqrt{S+BG}$

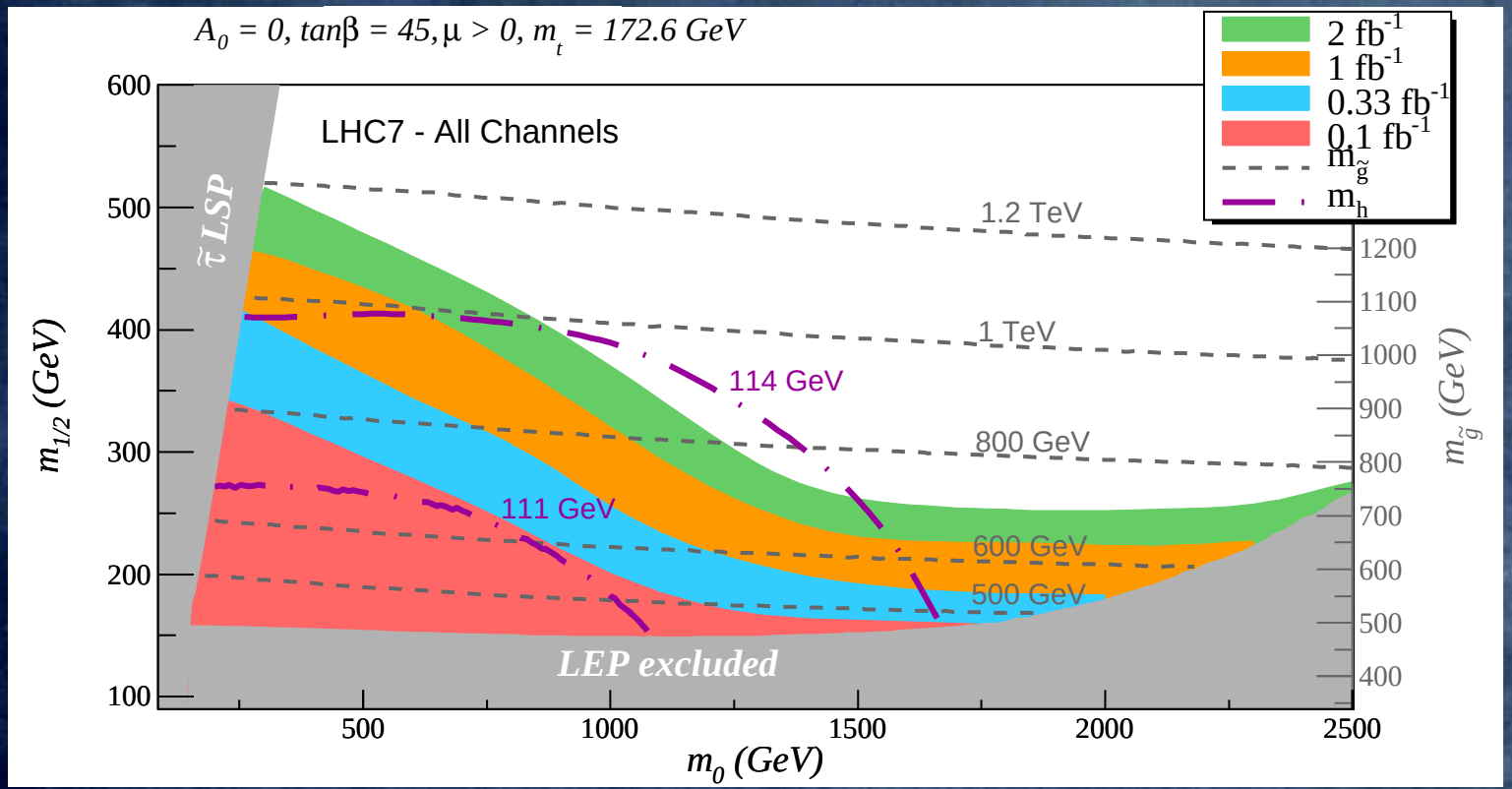
mSUGRA Reach

- Full Analysis results:



mSUGRA Reach

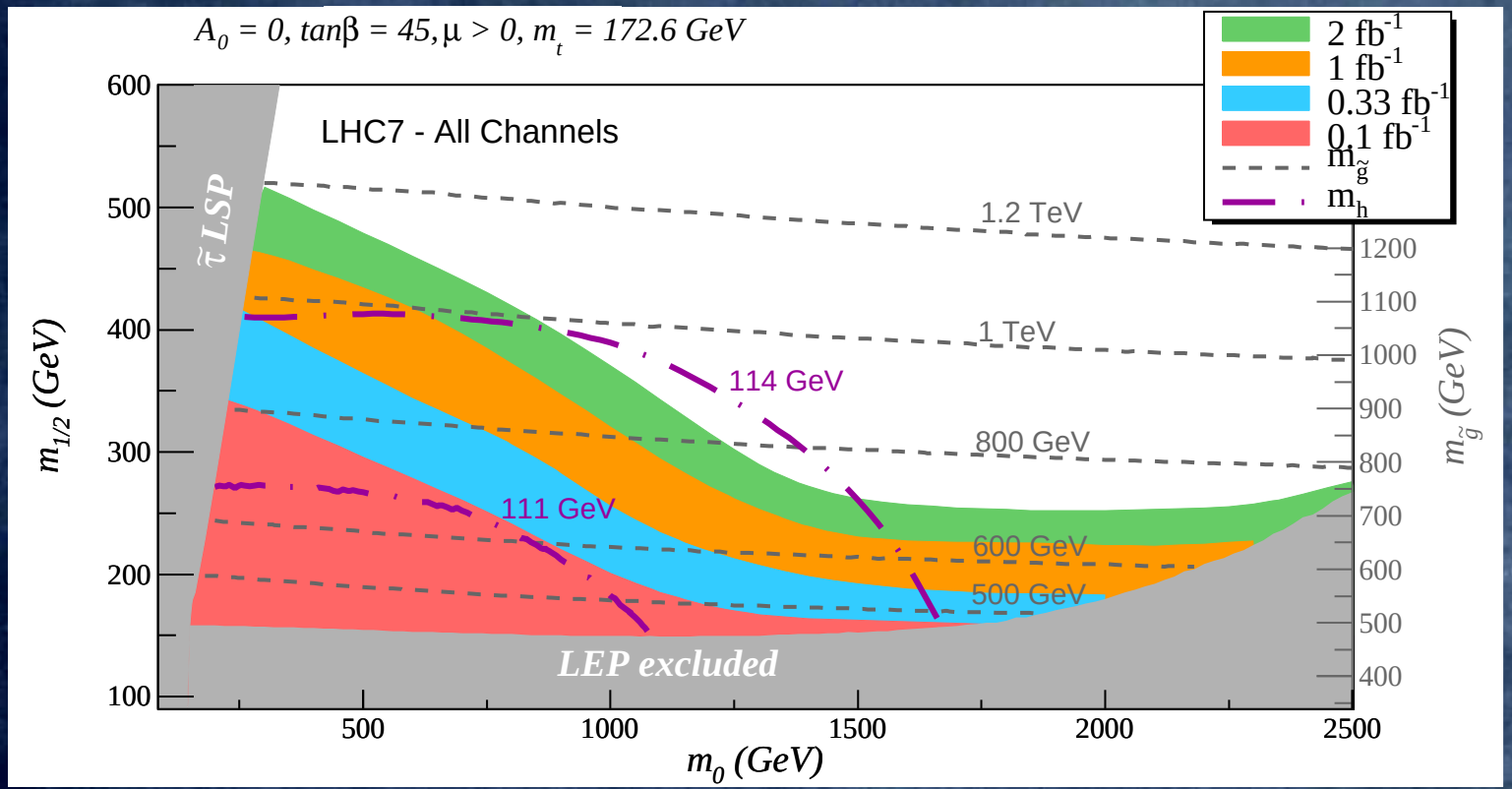
- Full Analysis results:



$$650 \text{ GeV} \lesssim m_{\tilde{g}} \lesssim 1.1 \text{ TeV}$$

mSUGRA Reach

- Full Analysis results:

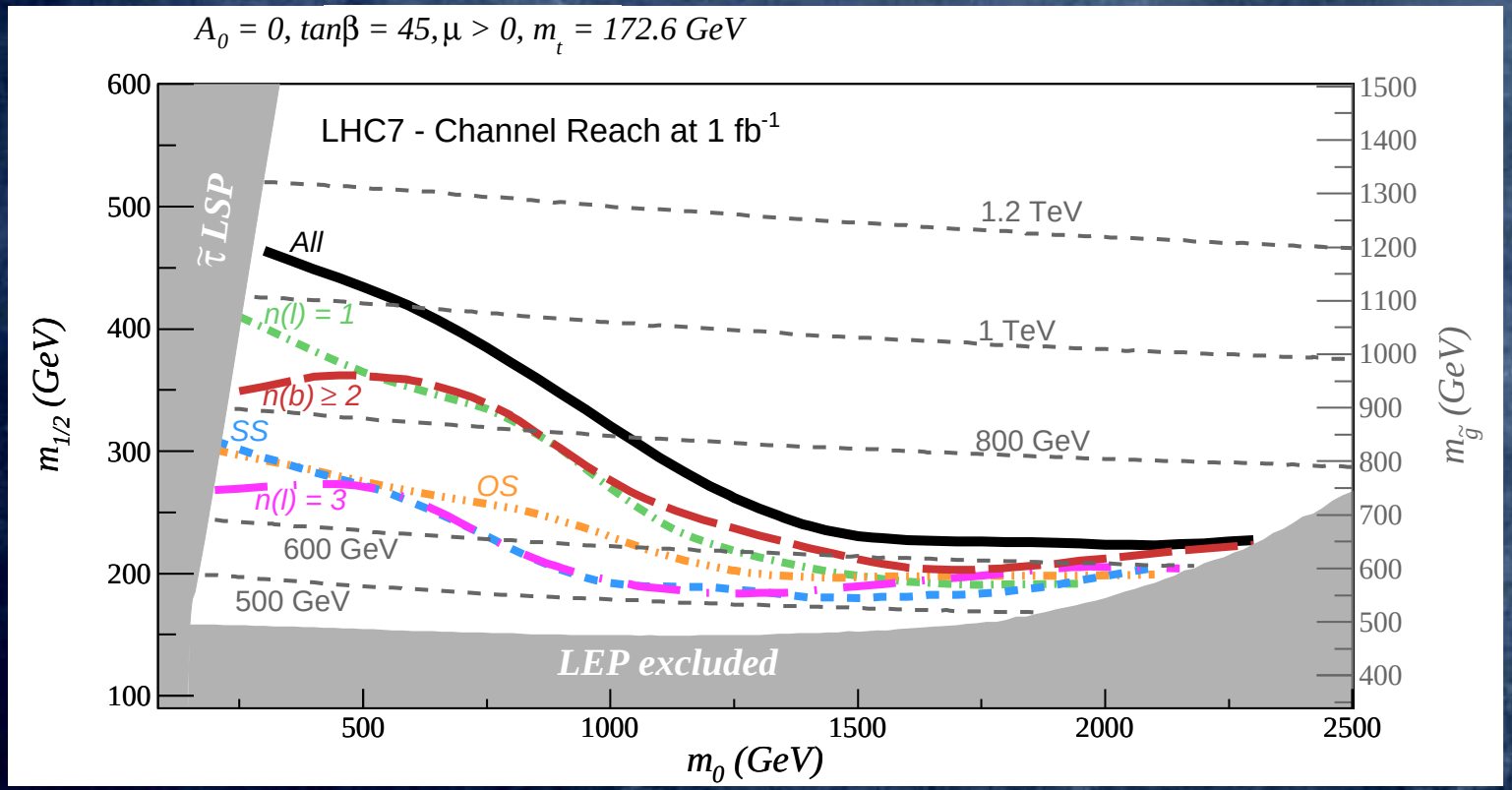


$$650 \text{ GeV} \lesssim m_{\tilde{g}} \lesssim 1.1 \text{ TeV}$$

$\Rightarrow$ Agrees with estimated reach!

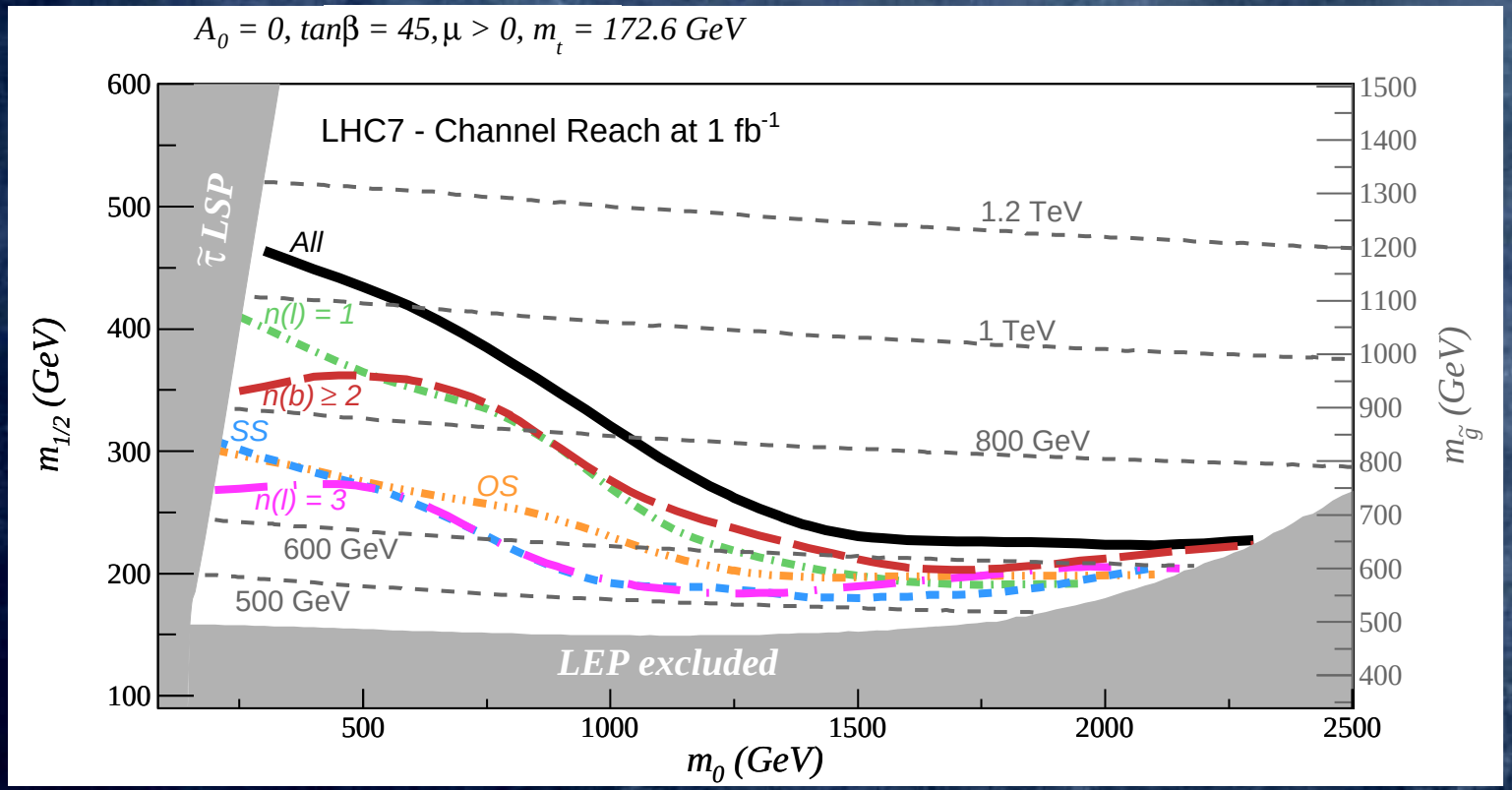
Reach X-Ray

- Which channels are relevant?



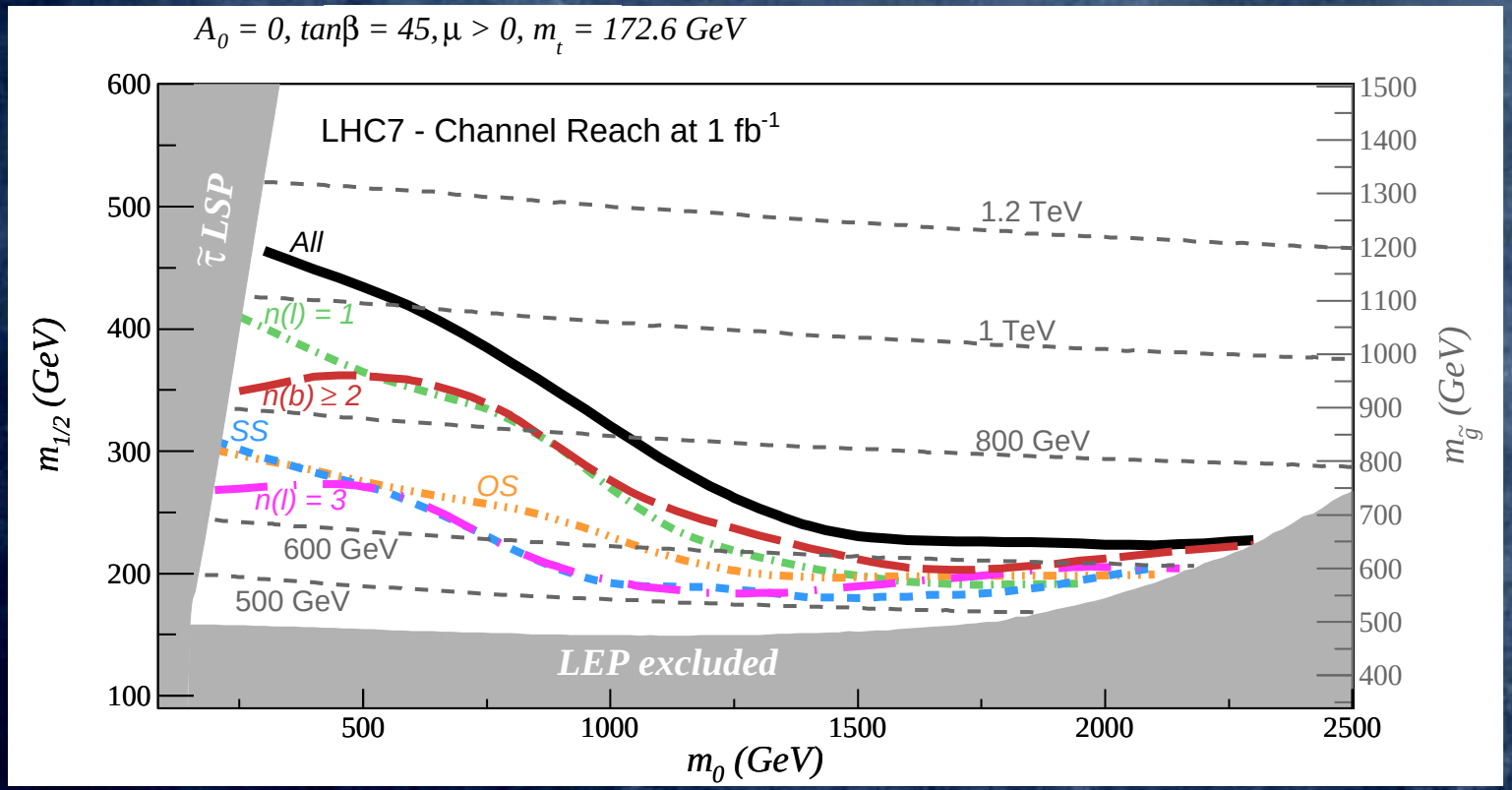
Reach X-Ray

- Which channels are relevant?
  - Multi-jets + $\not{E}_T$: largest cross-sections $\rightarrow$ maximum reach



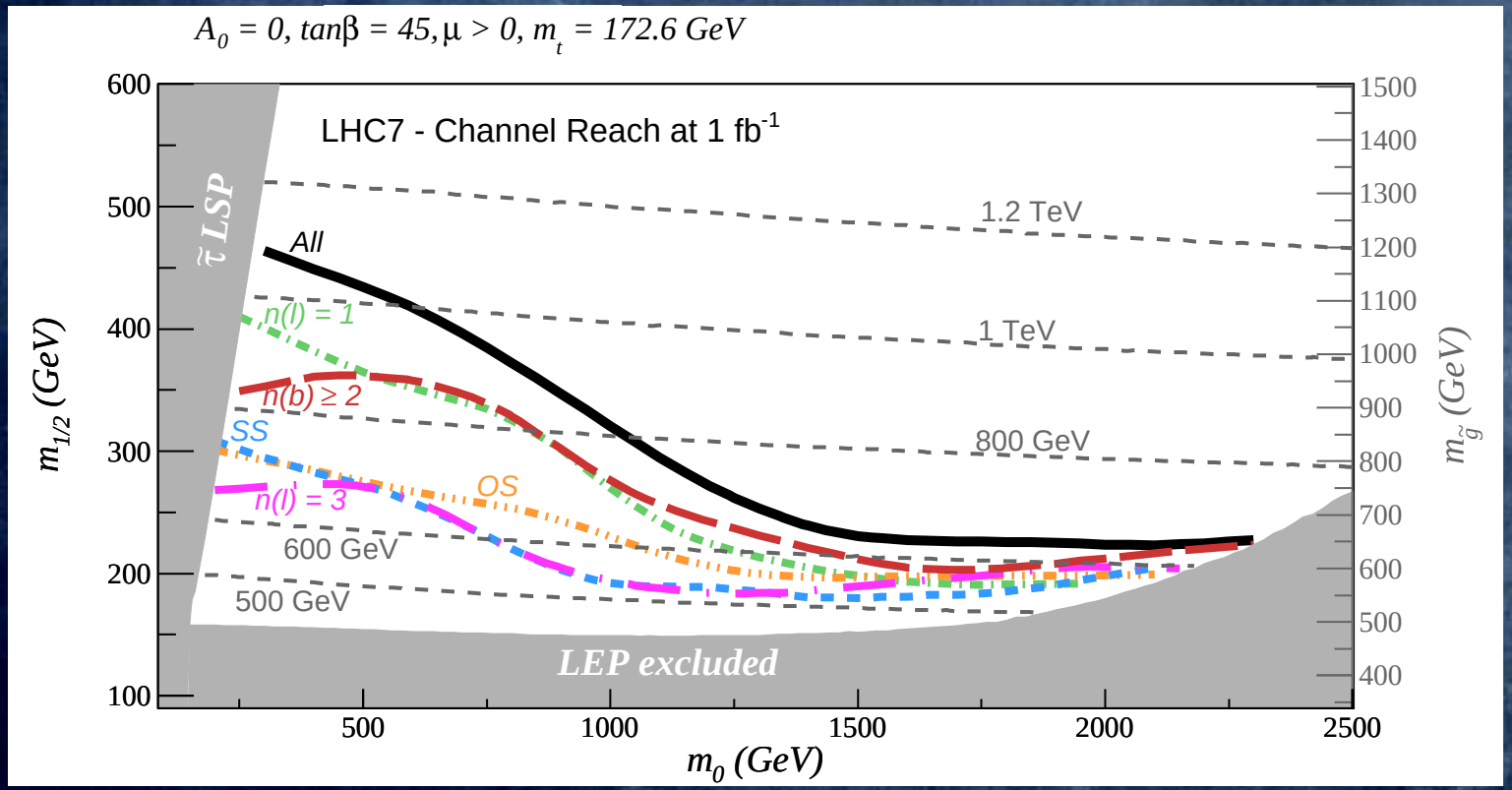
Reach X-Ray

- Which channels are relevant?
  - Multi-jets + $\not{E}_T$: largest cross-sections $\rightarrow$ maximum reach
  - Complementary signals:



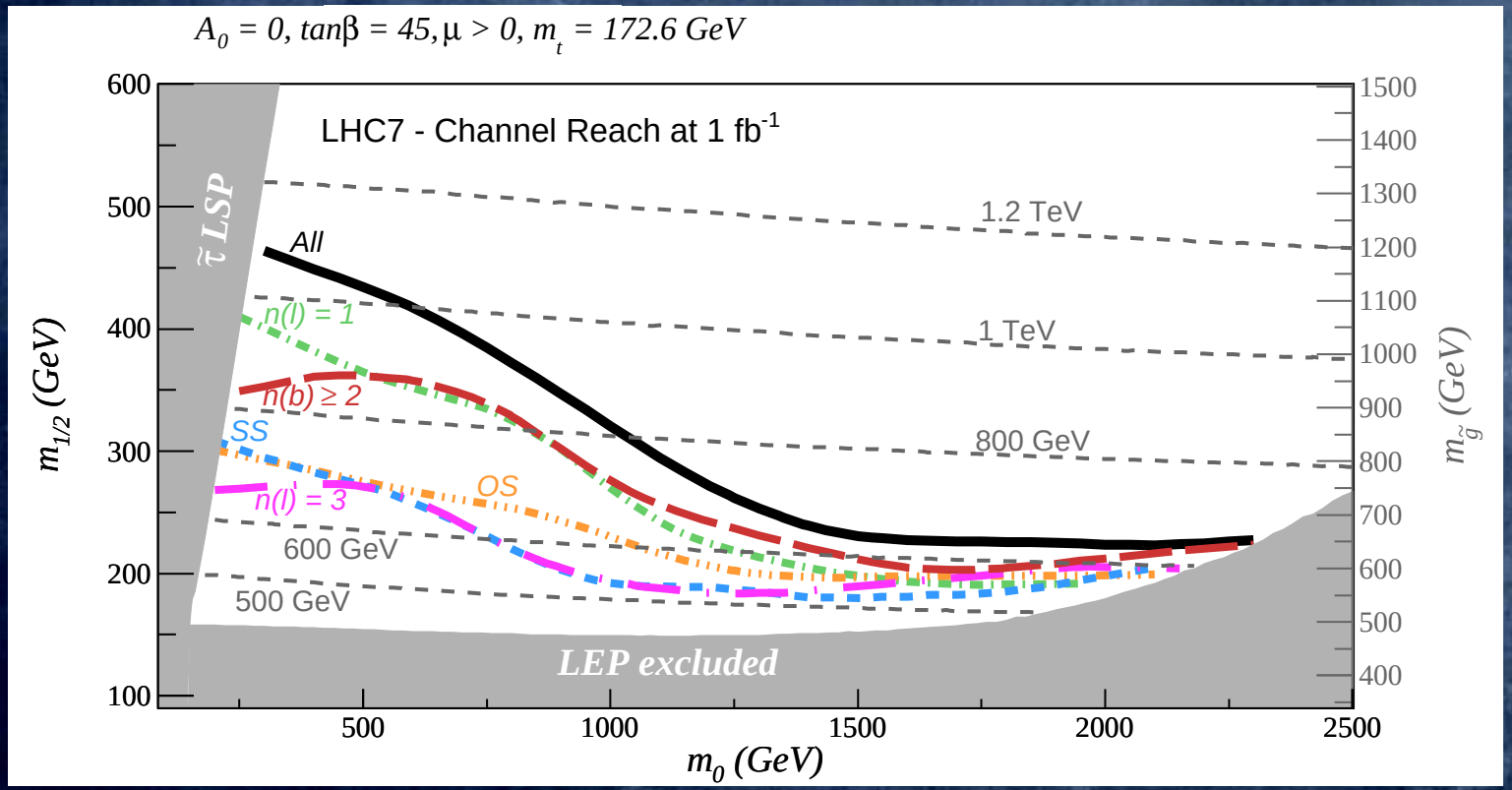
Reach X-Ray

- Which channels are relevant?
  - Multi-jets + $\not{E}_T$: largest cross-sections $\rightarrow$ maximum reach
  - Complementary signals:
    - Multi-b's

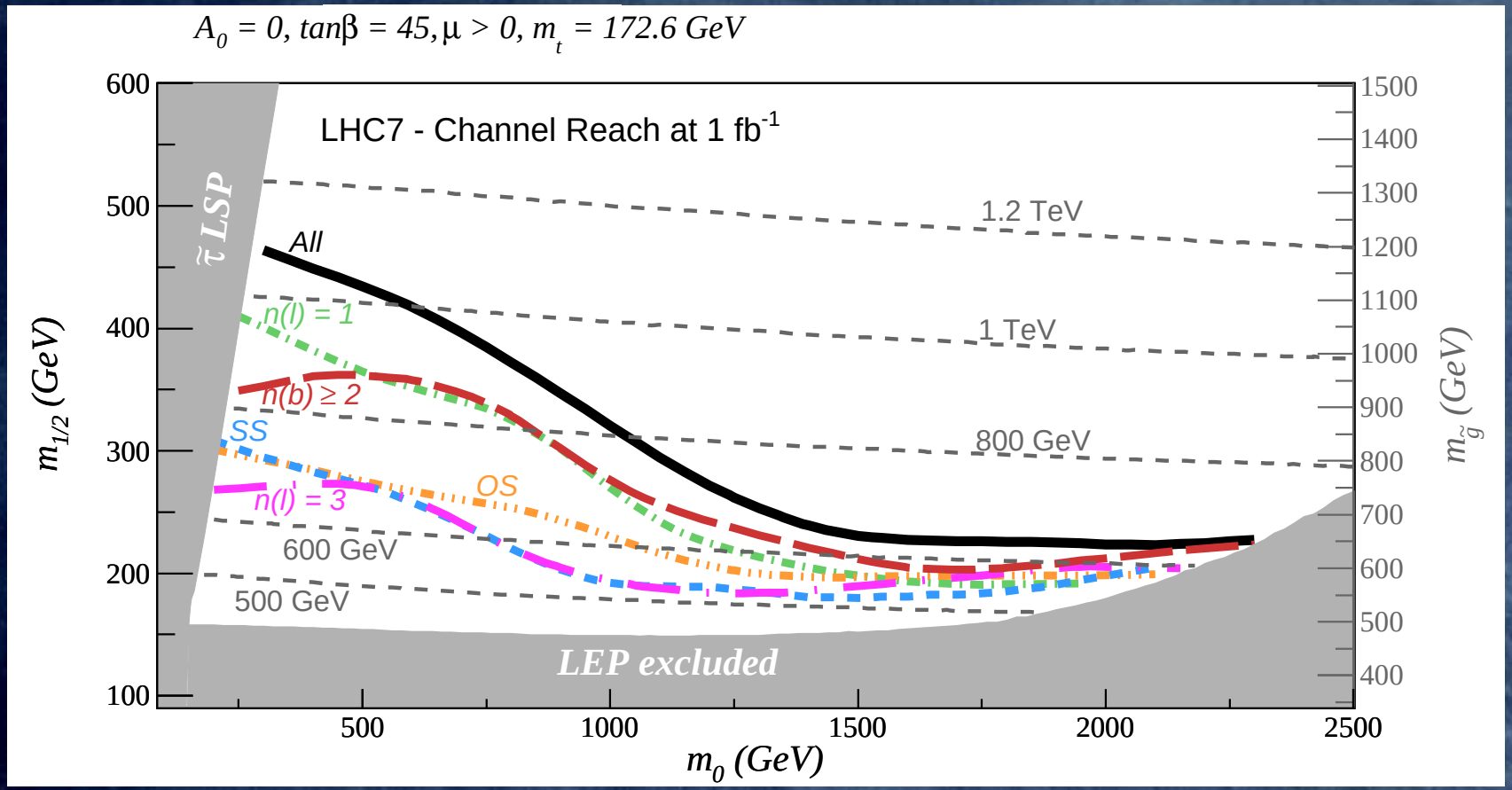


Reach X-Ray

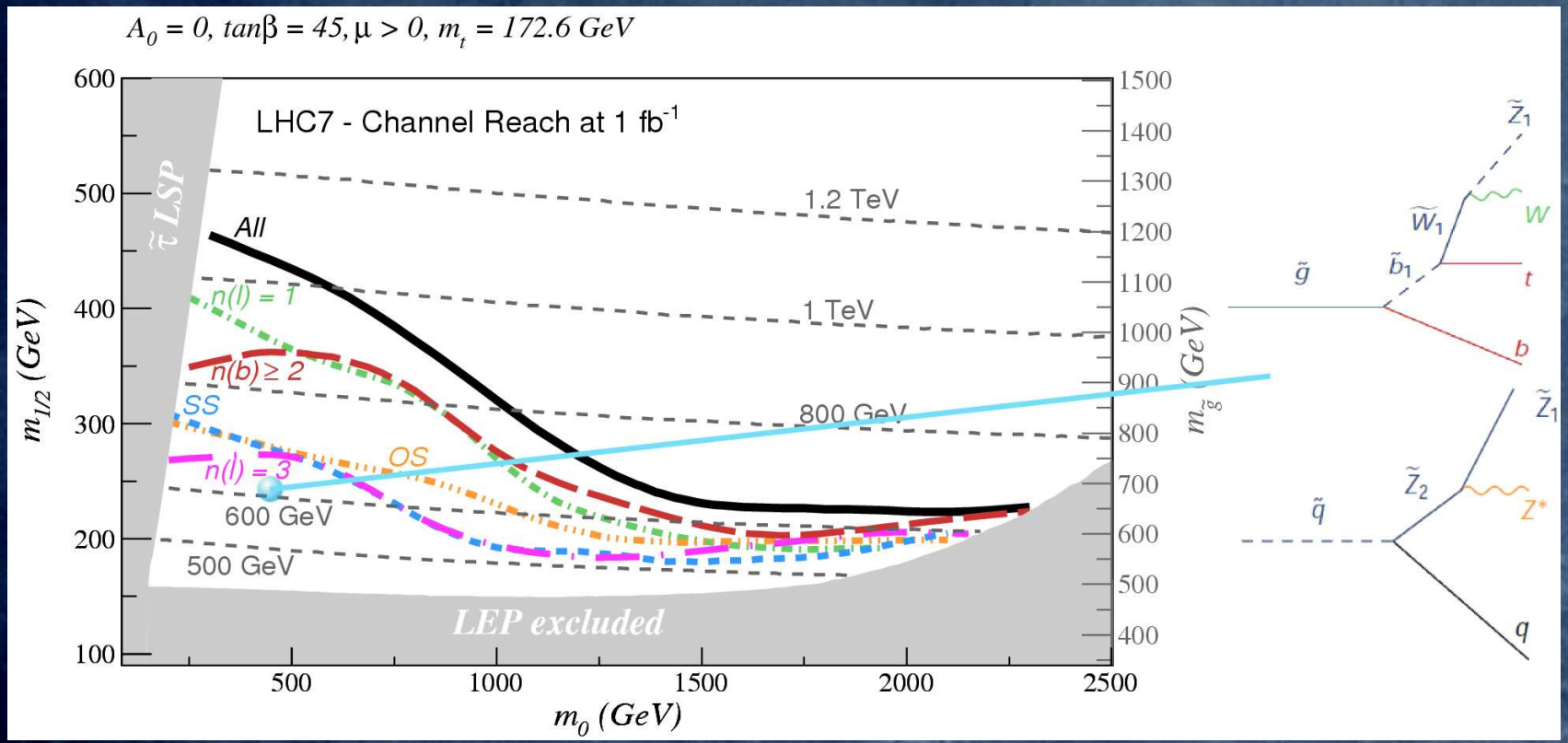
- Which channels are relevant?
  - Multi-jets + $\not{E}_T$: largest cross-sections $\rightarrow$ maximum reach
  - Complementary signals:
    - Multi-b's
    - Multi-leptons



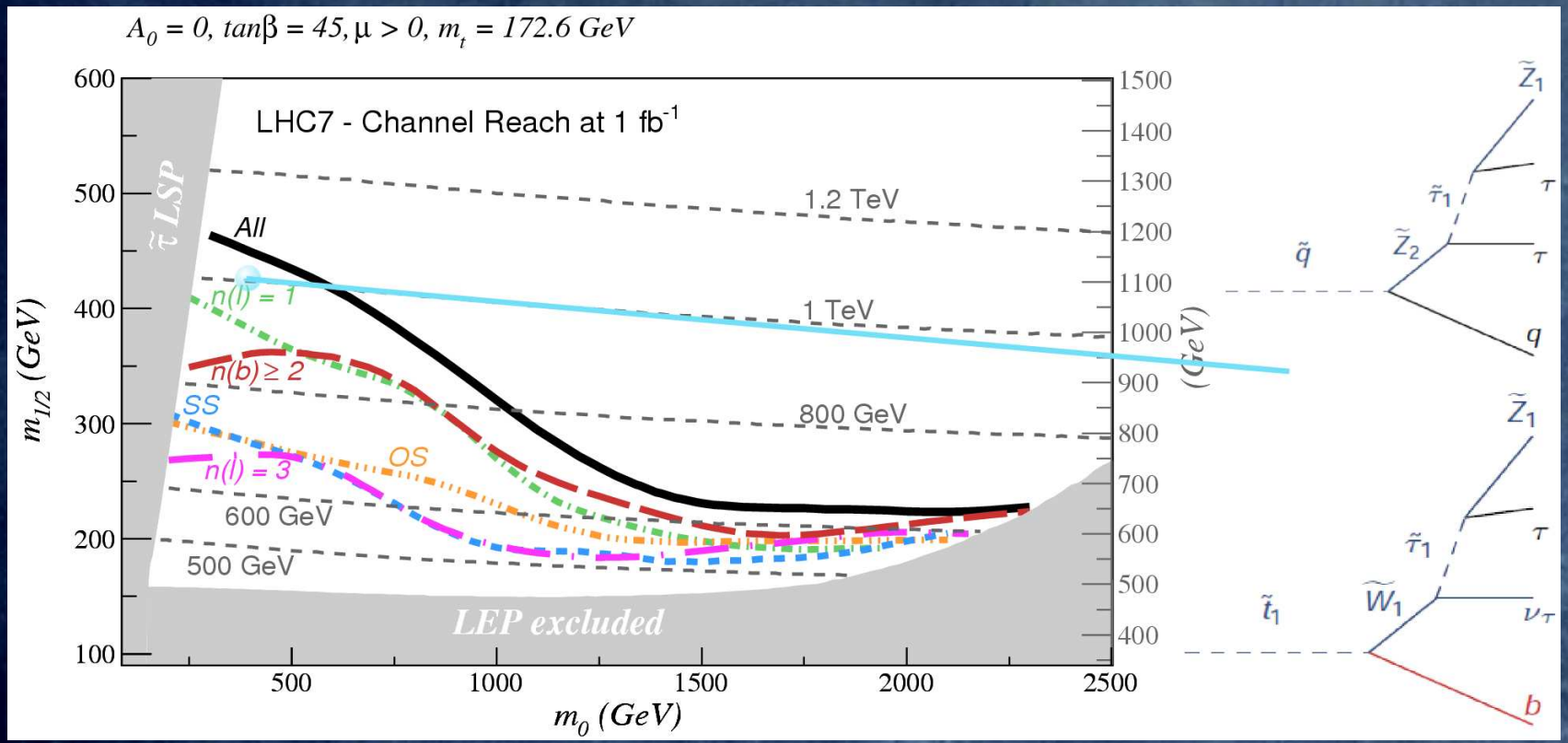
Reach X-Ray


$A_0 = 0$, $\tan\beta = 45$, $\mu > 0$, $m_t = 172.6$ GeV
LHC7 - Channel Reach at 1 fb^{-1}
$\tilde{\tau}$ LSP
All
n(l) = 1
n(b) ≥ 2
SS
OS
n(l) = 3
1.2 TeV
1 TeV
800 GeV
600 GeV
500 GeV
LEP excluded
$m_{1/2}$ (GeV)
m_0 (GeV)
$m_{\tilde{g}}$ (GeV)
600
500
400
300
200
100
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
500
1000
1500
2000
2500

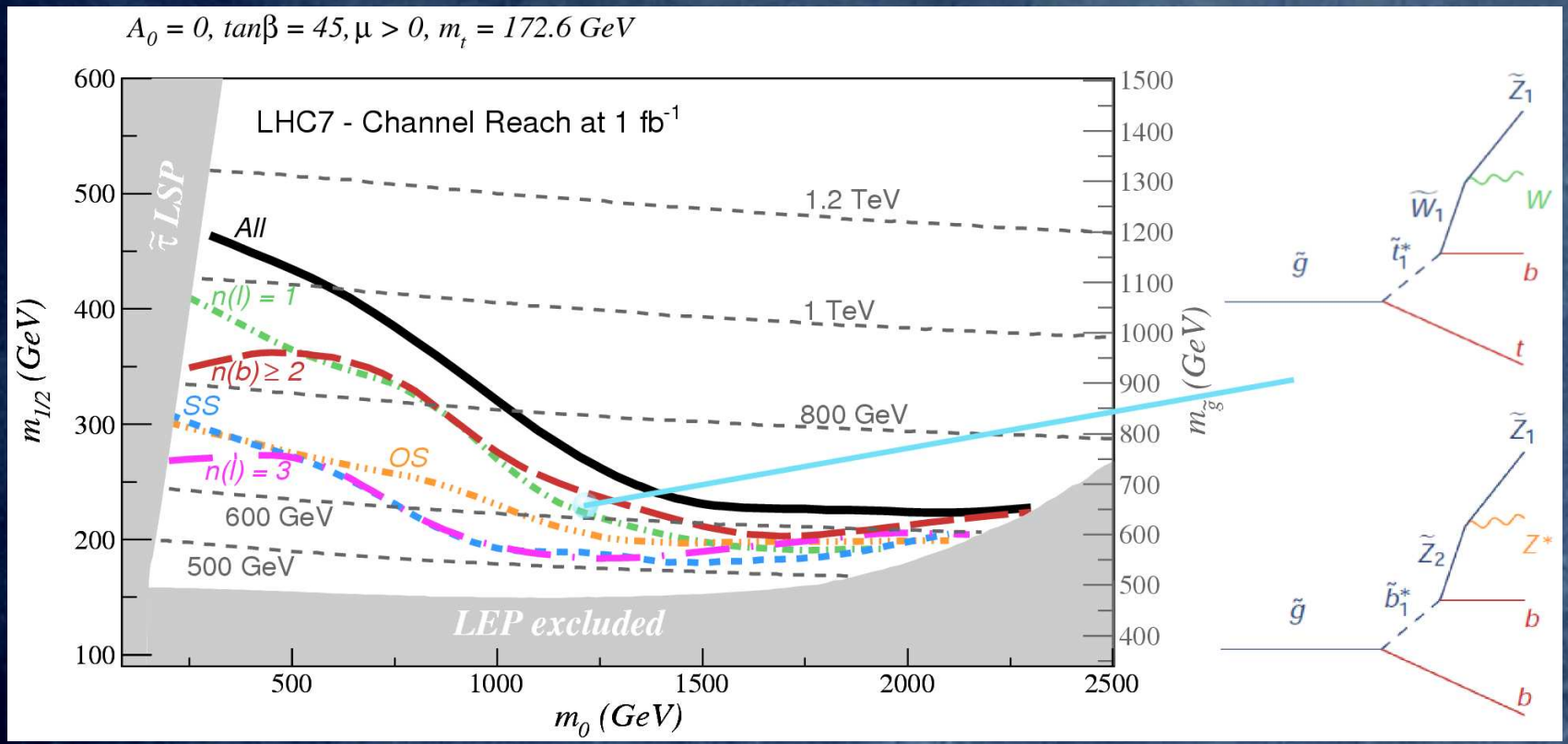
Reach X-Ray


$A_0 = 0$, $\tan\beta = 45$, $\mu > 0$, $m_t = 172.6$ GeV
LHC7 - Channel Reach at 1 fb^{-1}
$\tilde{\tau}$ LSP
All
n(l) = 1
n(b) ≥ 2
SS
OS
n(l) = 3
1.2 TeV
1 TeV
800 GeV
600 GeV
500 GeV
LEP excluded
$m_{1/2}$ (GeV)
m_0 (GeV)
$m_{\tilde{g}}$ (GeV)
$\tilde{g}$
$\tilde{b}_1$
$\tilde{W}_1$
$\tilde{Z}_1$
W
t
b
$\tilde{q}$
$\tilde{Z}_2$
Z*
q

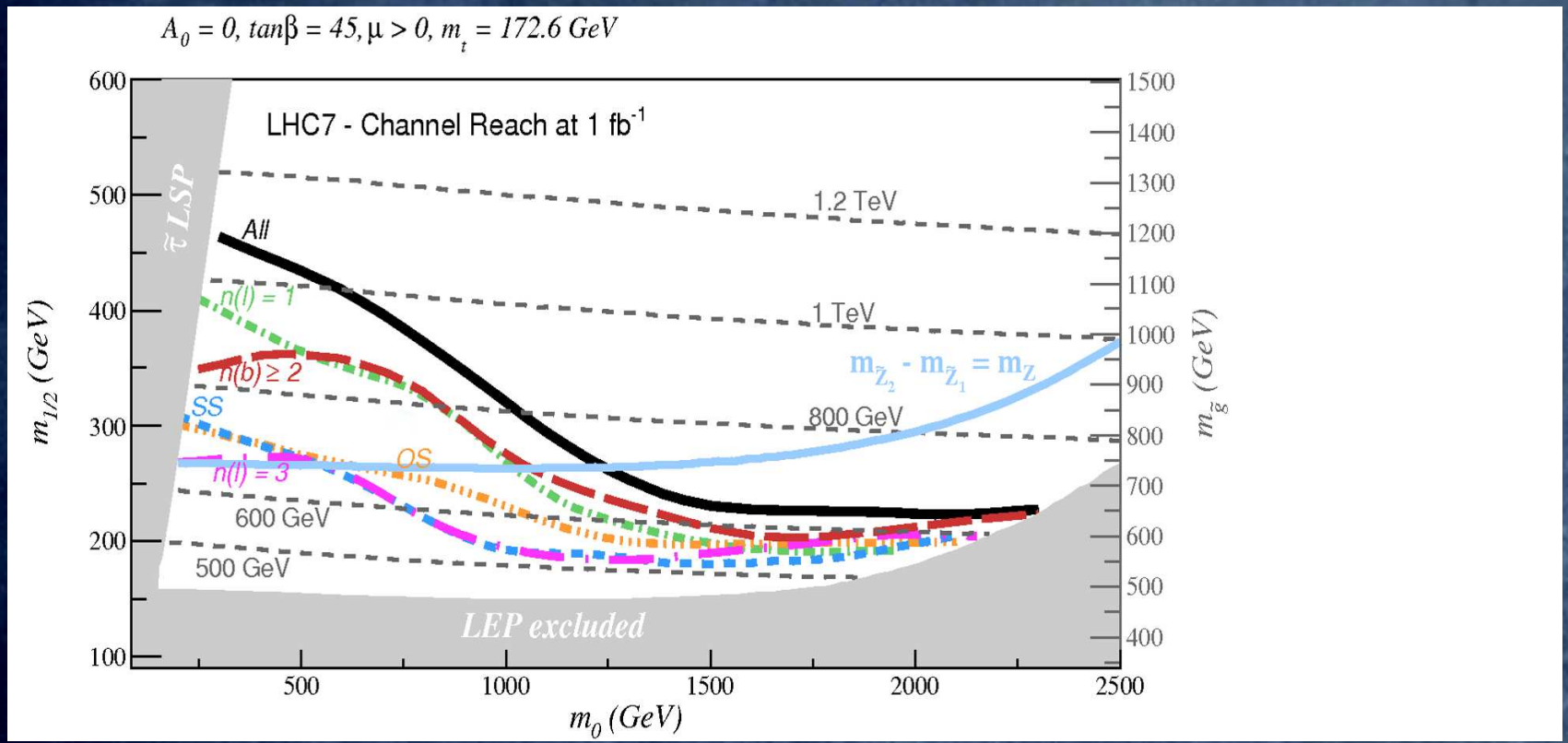
Reach X-Ray


$A_0 = 0$, $\tan\beta = 45$, $\mu > 0$, $m_t = 172.6$ GeV
LHC7 - Channel Reach at 1 fb^{-1}
$\tilde{\tau}$ LSP
All
n(l) = 1
n(b) ≥ 2
SS
OS
n(l) = 3
1.2 TeV
1 TeV
800 GeV
600 GeV
500 GeV
LEP excluded
$m_{1/2}$ (GeV)
m_0 (GeV)
$\tilde{q}$
$\tilde{t}_1$
$\tilde{Z}_1$
$\tilde{Z}_2$
$\tilde{\tau}_1$
$\tilde{W}_1$
τ
q
ν_τ
b

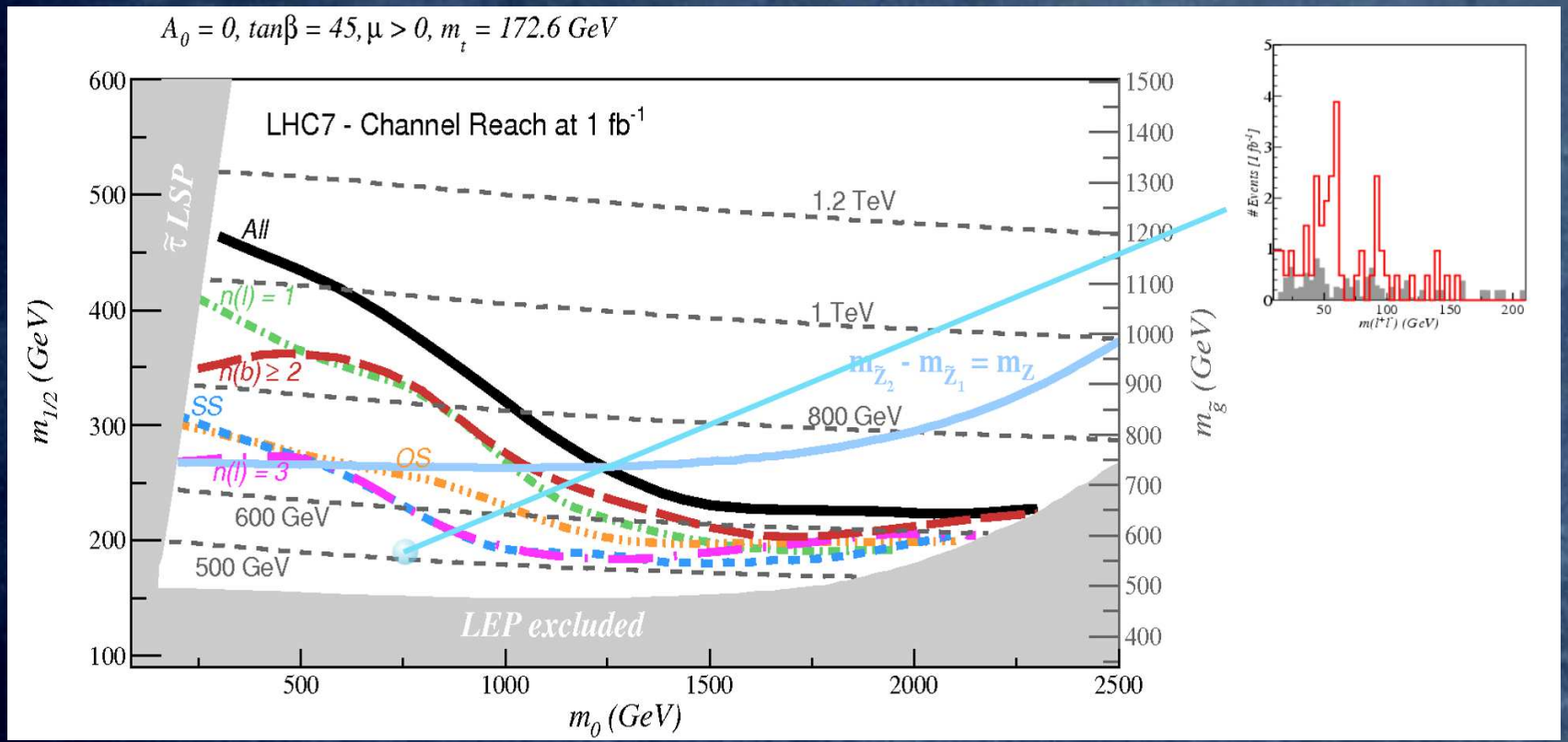
Reach X-Ray


$A_0 = 0$, $\tan\beta = 45$, $\mu > 0$, $m_t = 172.6$ GeV
LHC7 - Channel Reach at 1 fb^{-1}
$\tilde{\tau}$ LSP
All
n(l) = 1
n(b) ≥ 2
SS
OS
n(l) = 3
1.2 TeV
1 TeV
800 GeV
600 GeV
500 GeV
LEP excluded
$m_{1/2}$ (GeV)
m_0 (GeV)
$m_{\tilde{g}}$ (GeV)
$\tilde{Z}_1$
$\tilde{W}_1$
W
$\tilde{t}_1^*$
b
t
$\tilde{g}$
$\tilde{Z}_2$
Z*
$\tilde{b}_1^*$

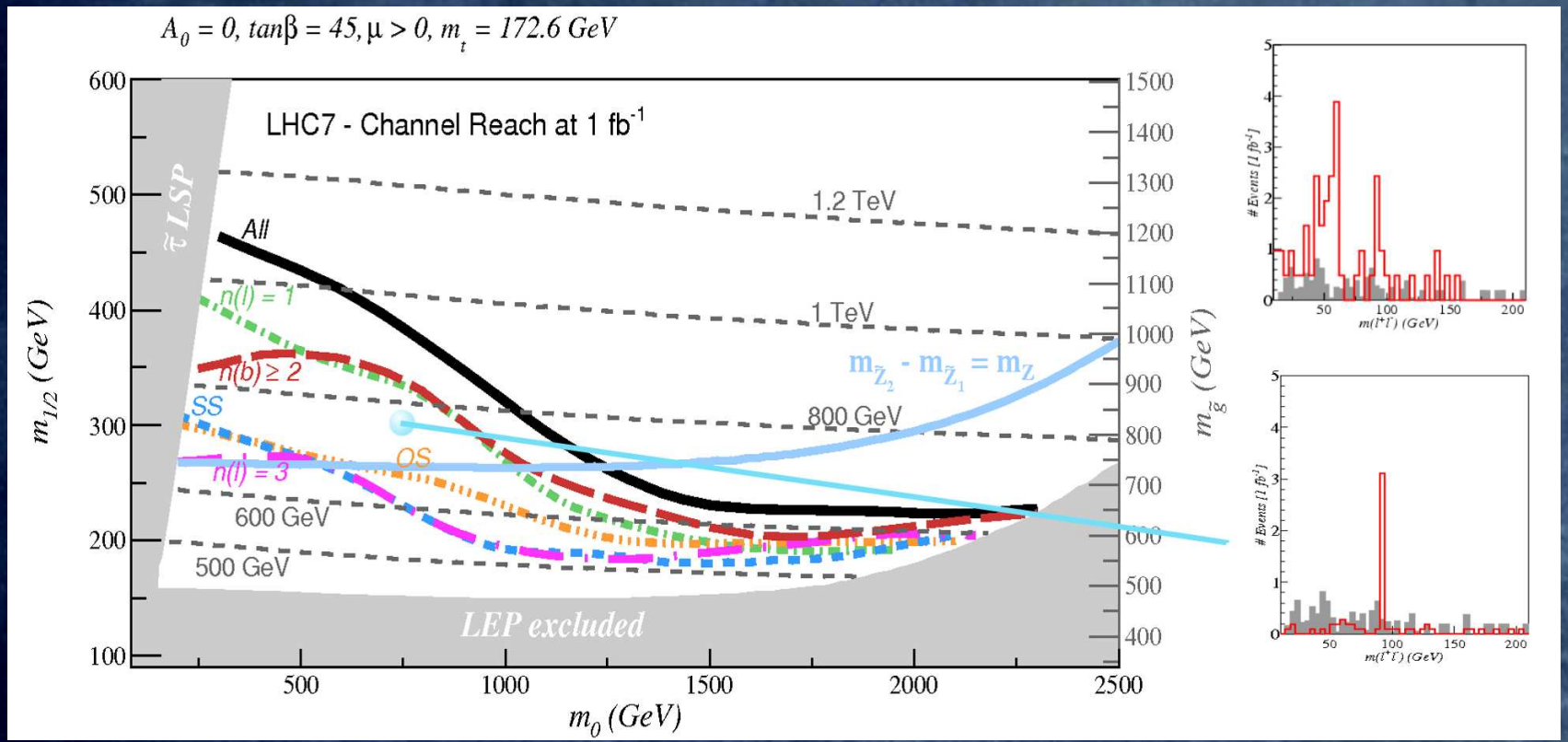
Reach X-Ray


$A_0 = 0, \tan\beta = 45, \mu > 0, m_t = 172.6\ GeV$
LHC7 - Channel Reach at 1 fb^{-1}
$\tilde{\tau}$ LSP
All
n(l) = 1
n(b) ≥ 2
SS
OS
n(l) = 3
1.2 TeV
1 TeV
800 GeV
600 GeV
500 GeV
$m_{\tilde{Z}_2} - m_{\tilde{Z}_1} = m_Z$
LEP excluded
$m_{1/2}$ (GeV)
$m_{\tilde{g}}$ (GeV)
m_0 (GeV)
600
500
400
300
200
100
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
500
1000
1500
2000
2500

Reach X-Ray


$A_0 = 0, \tan\beta = 45, \mu > 0, m_t = 172.6\ GeV$
LHC7 - Channel Reach at 1 fb^{-1}
$\tilde{\tau}$ LSP
All
n(l) = 1
n(b) ≥ 2
SS
OS
n(l) = 3
1.2 TeV
1 TeV
800 GeV
600 GeV
500 GeV
$m_{\tilde{Z}_2} - m_{\tilde{Z}_1} = m_Z$
LEP excluded
$m_{1/2}$ (GeV)
m_0 (GeV)
$m_{\tilde{g}}$ (GeV)
# Events [1 fb^{-1}]
m(l$^+$l$^-$) (GeV)

Reach X-Ray


$A_0 = 0, \tan\beta = 45, \mu > 0, m_t = 172.6\ GeV$
LHC7 - Channel Reach at 1 fb^{-1}
$\tilde{\tau}$ LSP
All
n(l) = 1
n(b) ≥ 2
SS
OS
n(l) = 3
1.2 TeV
1 TeV
800 GeV
600 GeV
500 GeV
LEP excluded
$m_{\tilde{Z}_2} - m_{\tilde{Z}_1} = m_Z$
$m_{1/2}$ (GeV)
m_0 (GeV)
$m_{\tilde{g}}$ (GeV)
# Events [1 fb^{-1}]
m(l$^+$l$^-$) (GeV)

mSUGRA Reach

- Some Benchmark points:

mSUGRA Reach

- Some Benchmark points:
- SPSla':
  $m_0 = 70$ GeV, $m_{1/2} = 250$ GeV, $A_0 =$ -300 GeV, $\tan\beta = 10$

mSUGRA Reach

- Some Benchmark points:
- SPSla':
  $m_0 = 70$ GeV, $m_{1/2} = 250$ GeV, $A_0 =$ -300 GeV, $\tan\beta = 10$
  - $m_{\tilde{g}} = 608$ GeV, $m_{\tilde{q}} \sim 550$ GeV, $m_{\tilde{Z}_1} = 98$ GeV, $m_{\tilde{\tau}_1} = 108$ GeV
  - $\Omega h^2 = 0.11$, $\delta a_\mu = 38 \times 10^{-10}$, $BF(b \to s\gamma) = 2.6 \times 10^{-4}$

mSUGRA Reach

- Some Benchmark points:
- SPSla':
  $m_0 = 70$ GeV, $m_{1/2} = 250$ GeV, $A_0 =$ -300 GeV, $\tan\beta = 10$
  - $m_{\tilde{g}} = 608$ GeV, $m_{\tilde{q}} \sim 550$ GeV, $m_{\tilde{Z}_1} = 98$ GeV, $m_{\tilde{\tau}_1} = 108$ GeV
  - $\Omega h^2 = 0.11$, $\delta a_\mu = 38 \times 10^{-10}$, $BF(b \to s\gamma) = 2.6 \times 10^{-4}$
  - **Visible at:** $n(j) \geq 2$, $\not{E}_T > 200$ **GeV,** $(S = 909, BG = 460)$

mSUGRA Reach

- Some Benchmark points:
- SPSla':
  $m_0 = 70$ GeV, $m_{1/2} = 250$ GeV, $A_0 =$ -300 GeV, $\tan\beta = 10$
  - $m_{\tilde{g}} = 608$ GeV, $m_{\tilde{q}} \sim 550$ GeV, $m_{\tilde{Z}_1} = 98$ GeV, $m_{\tilde{\tau}_1} = 108$ GeV
  - $\Omega h^2 = 0.11$, $\delta a_\mu = 38 \times 10^{-10}$, $BF(b \to s\gamma) = 2.6 \times 10^{-4}$
  - **Visible at:** $n(j) \geq 2$, $\not{E}_T > 200$ **GeV,** $(S = 909, BG = 460)$
- mSUGRA Best Fit:
  $m_0 = 60$ GeV, $m_{1/2} = 310$ GeV, $A_0 = 130$ GeV, $\tan\beta = 11$
  (O. Buchmueller et al., Eur.Phys.J.C64:391-415,2009)

mSUGRA Reach

- Some Benchmark points:
- SPSla':
  $m_0 = 70$ GeV, $m_{1/2} = 250$ GeV, $A_0 =$ -300 GeV, $\tan\beta = 10$
  - $m_{\tilde{g}} = 608$ GeV, $m_{\tilde{q}} \sim 550$ GeV, $m_{\tilde{Z}_1} = 98$ GeV, $m_{\tilde{\tau}_1} = 108$ GeV
  - $\Omega h^2 = 0.11$, $\delta a_\mu = 38 \times 10^{-10}$, $BF(b \to s\gamma) = 2.6 \times 10^{-4}$
  - **Visible at:** $n(j) \geq 2$, $\not{E}_T > 200$ **GeV,** $(S = 909, BG = 460)$
- mSUGRA Best Fit:
  $m_0 = 60$ GeV, $m_{1/2} = 310$ GeV, $A_0 = 130$ GeV, $\tan\beta = 11$
  (O. Buchmueller et al., Eur.Phys.J.C64:391-415,2009)
  - $m_{\tilde{g}} = 740$ GeV, $m_{\tilde{q}} \sim 650$ GeV, $m_{\tilde{Z}_1} = 122$ GeV, $m_{\tilde{\tau}_1} = 129$ GeV
  - $\Omega h^2 = 0.08$, $\delta a_\mu = 27 \times 10^{-10}$, $BF(b \to s\gamma) = 3.1 \times 10^{-4}$

mSUGRA Reach

- Some Benchmark points:
- SPSla':
  $m_0 = 70$ GeV, $m_{1/2} = 250$ GeV, $A_0 =$ -300 GeV, $\tan\beta = 10$
  - $m_{\tilde{g}} = 608$ GeV, $m_{\tilde{q}} \sim 550$ GeV, $m_{\tilde{Z}_1} = 98$ GeV, $m_{\tilde{\tau}_1} = 108$ GeV
  - $\Omega h^2 = 0.11$, $\delta a_\mu = 38 \times 10^{-10}$, $BF(b \to s\gamma) = 2.6 \times 10^{-4}$
  - **Visible at:** $n(j) \geq 2$, $\not{E}_T > 200$ **GeV,** $(S = 909, BG = 460)$
- mSUGRA Best Fit:
  $m_0 = 60$ GeV, $m_{1/2} = 310$ GeV, $A_0 = 130$ GeV, $\tan\beta = 11$
  (O. Buchmueller et al., Eur.Phys.J.C64:391-415,2009)
  - $m_{\tilde{g}} = 740$ GeV, $m_{\tilde{q}} \sim 650$ GeV, $m_{\tilde{Z}_1} = 122$ GeV, $m_{\tilde{\tau}_1} = 129$ GeV
  - $\Omega h^2 = 0.08$, $\delta a_\mu = 27 \times 10^{-10}$, $BF(b \to s\gamma) = 3.1 \times 10^{-4}$
  - **Visible at:** $n(j) \geq 2$, $\not{E}_T > 300$ **GeV,** $(S = 221, BG = 109)$

mSUGRA Reach

mSUGRA Reach

- mSUGRA Best Fit (FP):
  $m_0 = 2550$ GeV, $m_{1/2} = 370$ GeV, $A_0 = 1730$ GeV, $\tan\beta = 51$

mSUGRA Reach

- mSUGRA Best Fit (FP):
  $m_0 = 2550$ GeV, $m_{1/2} = 370$ GeV, $A_0 = 1730$ GeV, $\tan\beta = 51$
  - $m_{\tilde{g}} = 980$ GeV, $m_{\tilde{q}} \sim 2500$ GeV, $m_{\tilde{Z}_1} = 154$ GeV
  - $\Omega h^2 = 4.4$, $\delta a_\mu = 3 \times 10^{-10}$, $BF(b \to s\gamma) = 3.1 \times 10^{-4}$

mSUGRA Reach

- mSUGRA Best Fit (FP):
  $m_0 = 2550$ GeV, $m_{1/2} = 370$ GeV, $A_0 = 1730$ GeV, $\tan\beta = 51$
  - $m_{\tilde{g}} = 980$ GeV, $m_{\tilde{q}} \sim 2500$ GeV, $m_{\tilde{Z}_1} = 154$ GeV
  - $\Omega h^2 = 4.4$, $\delta a_\mu = 3 \times 10^{-10}$, $BF(b \to s\gamma) = 3.1 \times 10^{-4}$
  - **Not visible!**

mSUGRA Reach

- mSUGRA Best Fit (FP):
  $m_0 = 2550$ GeV, $m_{1/2} = 370$ GeV, $A_0 = 1730$ GeV, $\tan\beta = 51$
  - $m_{\tilde{g}} = 980$ GeV, $m_{\tilde{q}} \sim 2500$ GeV, $m_{\tilde{Z}_1} = 154$ GeV
  - $\Omega h^2 = 4.4$, $\delta a_\mu = 3 \times 10^{-10}$, $BF(b \to s\gamma) = 3.1 \times 10^{-4}$
  - **Not visible!**
- NUHM1 Best Fit:
  $m_0 = 150$ GeV, $m_{1/2} = 270$ GeV, $m_H = 1095$ GeV, $A_0 = -1300$ GeV, $\tan\beta = 11$

mSUGRA Reach

- **mSUGRA Best Fit (FP):**
  $m_0 = 2550$ GeV, $m_{1/2} = 370$ GeV, $A_0 = 1730$ GeV, $\tan\beta = 51$
  - $m_{\tilde{g}} = 980$ GeV, $m_{\tilde{q}} \sim 2500$ GeV, $m_{\tilde{Z}_1} = 154$ GeV
  - $\Omega h^2 = 4.4$, $\delta a_\mu = 3 \times 10^{-10}$, $BF(b \to s\gamma) = 3.1 \times 10^{-4}$
  - **Not visible!**
- **NUHM1 Best Fit:**
  $m_0 = 150$ GeV, $m_{1/2} = 270$ GeV, $m_H = 1095$ GeV, $A_0 =$ -1300 GeV, $\tan\beta = 11$
  - $m_{\tilde{g}} = 658$ GeV, $m_{\tilde{q}} \sim 600$ GeV, $m_{\tilde{Z}_1} = 110$ GeV
  - $\Omega h^2 = 0.05$, $\delta a_\mu = 33 \times 10^{-10}$, $BF(b \to s\gamma) = 3.9 \times 10^{-4}$

mSUGRA Reach

- **mSUGRA Best Fit (FP):**
  $m_0 = 2550$ GeV, $m_{1/2} = 370$ GeV, $A_0 = 1730$ GeV, $\tan\beta = 51$
  - $m_{\tilde{g}} = 980$ GeV, $m_{\tilde{q}} \sim 2500$ GeV, $m_{\tilde{Z}_1} = 154$ GeV
  - $\Omega h^2 = 4.4$, $\delta a_\mu = 3 \times 10^{-10}$, $BF(b \to s\gamma) = 3.1 \times 10^{-4}$
  - **Not visible!**
- **NUHM1 Best Fit:**
  $m_0 = 150$ GeV, $m_{1/2} = 270$ GeV, $m_H = 1095$ GeV, $A_0 =$ -1300 GeV, $\tan\beta = 11$
  - $m_{\tilde{g}} = 658$ GeV, $m_{\tilde{q}} \sim 600$ GeV, $m_{\tilde{Z}_1} = 110$ GeV
  - $\Omega h^2 = 0.05$, $\delta a_\mu = 33 \times 10^{-10}$, $BF(b \to s\gamma) = 3.9 \times 10^{-4}$
  - **Visible at:** $n(j) \geq 2$, $\not{E}_T > 300$ **GeV,** $(S = 465, BG = 124)$

Non mSUGRA Models

- How much of the previous results are model dependent?

(H. Baer, S. Kraml, A. Lessa and S. Sekmen, JHEP 1002:055, 2010)

Non mSUGRA Models

- How much of the previous results are model dependent?
- Example: Minimal SO(10) (DR3)

(H. Baer, S. Kraml, A. Lessa and S. Sekmen, JHEP 1002:055, 2010)

Non mSUGRA Models

- How much of the previous results are model dependent?
- Example: Minimal SO(10) (DR3)
  - Only one **10** Higgs:
    $W = f\Psi_3\Gamma_a\Psi_3 H_a + ... \Rightarrow f_t = f_b = f_\tau$ ($\gtrsim M_{GUT}$)

(H. Baer, S. Kraml, A. Lessa and S. Sekmen, JHEP 1002:055, 2010)

Non mSUGRA Models

- How much of the previous results are model dependent?
- Example: Minimal SO(10) (DR3)
  - Only one **10** Higgs:
    $W = f\Psi_3\Gamma_a\Psi_3 H_a + ... \Rightarrow f_t = f_b = f_\tau$ ($\gtrsim M_{GUT}$)
  - $m_{16}, m_{10}, \mathbf{M}_D, m_{1/2}, A_0, \tan\beta, sign(\mu)$

$$m_Q^2 = m_E^2 = m_U^2 = m_{16}^2 + M_D^2$$
$$m_D^2 = m_L^2 = m_{16}^2 - 3M_D^2$$
$$m_{\nu^c}^2 = m_{16}^2 + 5M_D^2$$
$$\mathbf{m_{H_u} = m_{10}^2 - 2M_D^2},\ \mathbf{m_{H_d} = m_{10}^2 + 2M_D^2}$$

(H. Baer, S. Kraml, A. Lessa and S. Sekmen, JHEP 1002:055, 2010)

Non mSUGRA Models

- How much of the previous results are model dependent?
- Example: Minimal SO(10) (DR3)
  - Only one **10** Higgs:
    $W = f\Psi_3\Gamma_a\Psi_3 H_a + ... \Rightarrow f_t = f_b = f_\tau$ ($\gtrsim M_{GUT}$)
  - $m_{16}, m_{10}, \mathbf{M}_D, m_{1/2}, A_0, \tan\beta, sign(\mu)$

$$m_Q^2 = m_E^2 = m_U^2 = m_{16}^2 + M_D^2$$
$$m_D^2 = m_L^2 = m_{16}^2 - 3M_D^2$$
$$m_{\nu^c}^2 = m_{16}^2 + 5M_D^2$$
$$\mathbf{m_{H_u} = m_{10}^2 - 2M_D^2},\ \mathbf{m_{H_d} = m_{10}^2 + 2M_D^2}$$

- Benchmark point (DR3B):
  $m_{16} = 12$ TeV, $m_{16}(3) = 11$ TeV, $m_{10} = 14$ TeV,
  $m_{1/2} = 27$ GeV, $M_D = 1.9$ TeV, $A_0 = -2.3$ TeV, $\tan\beta = 50$

(H. Baer, S. Kraml, A. Lessa and S. Sekmen, JHEP 1002:055, 2010)

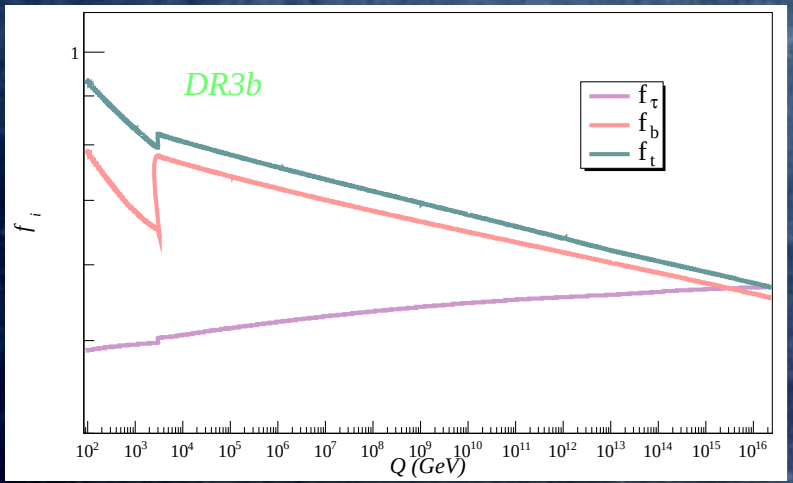
DR3B Model

- Spectrum:
  $m_{\tilde{g}} = 321$ GeV, $m_{\widetilde{W}_1} = 115$ GeV,
  $m_{\widetilde{Z}_2} = 114$ GeV,
  $m_{\widetilde{Z}_1} = 47$ GeV, $m_h = 129$ GeV
  $m_{\tilde{t}_1} = 2.4$ TeV, $m_{\tilde{b}_1} = 1.4$ TeV

DR3B Model

- Spectrum:

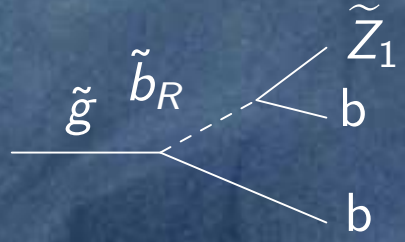
  $m_{\tilde{g}} = 321$ GeV, $m_{\widetilde{W}_1} = 115$ GeV,
  $m_{\widetilde{Z}_2} = 114$ GeV,
  $m_{\widetilde{Z}_1} = 47$ GeV, $m_h = 129$ GeV
  $m_{\tilde{t}_1} = 2.4$ TeV, $m_{\tilde{b}_1} = 1.4$ TeV

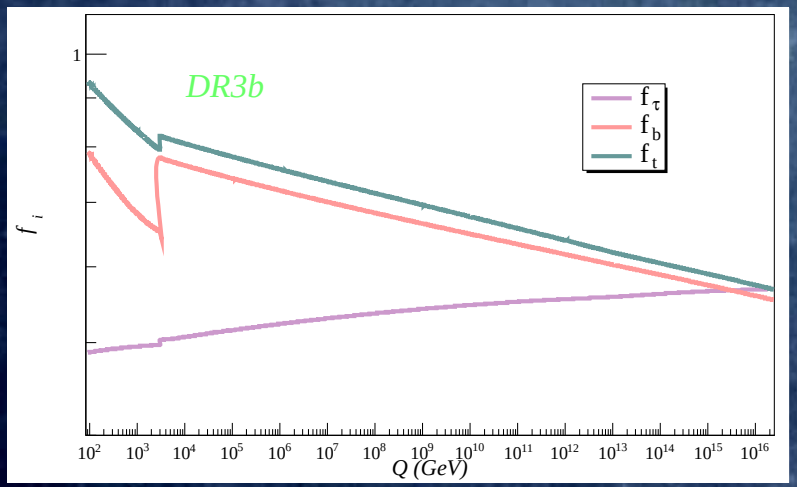


DR3B Model

- Spectrum:

  $m_{\tilde{g}} = 321$ GeV, $m_{\widetilde{W}_1} = 115$ GeV,
  $m_{\widetilde{Z}_2} = 114$ GeV,
  $m_{\widetilde{Z}_1} = 47$ GeV, $m_h = 129$ GeV
  $m_{\tilde{t}_1} = 2.4$ TeV, $m_{\tilde{b}_1} = 1.4$ TeV

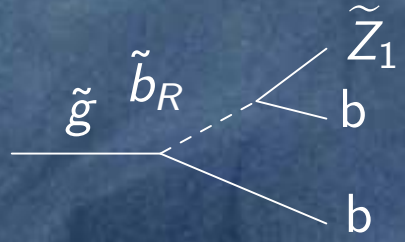


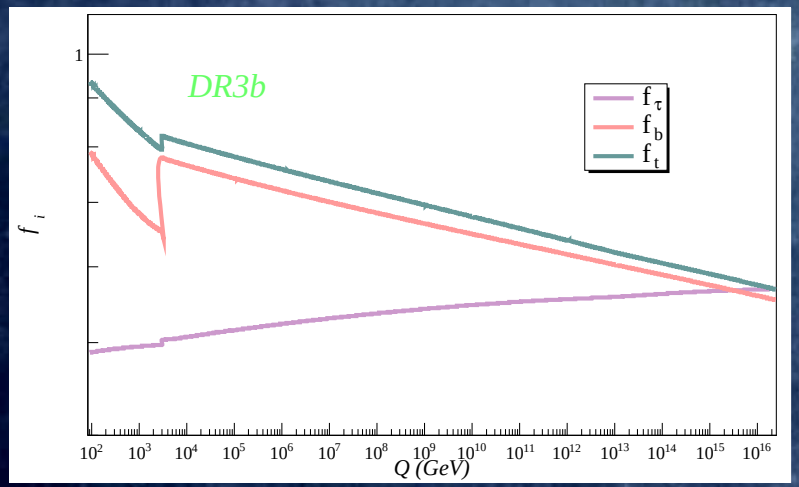


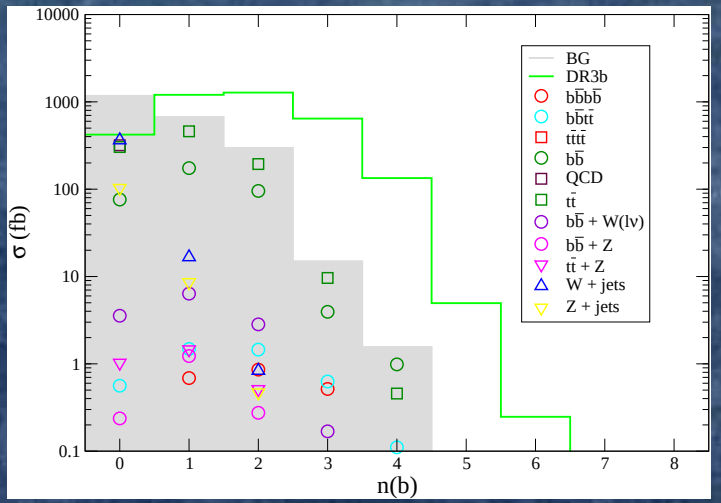
DR3B Model

- Spectrum:

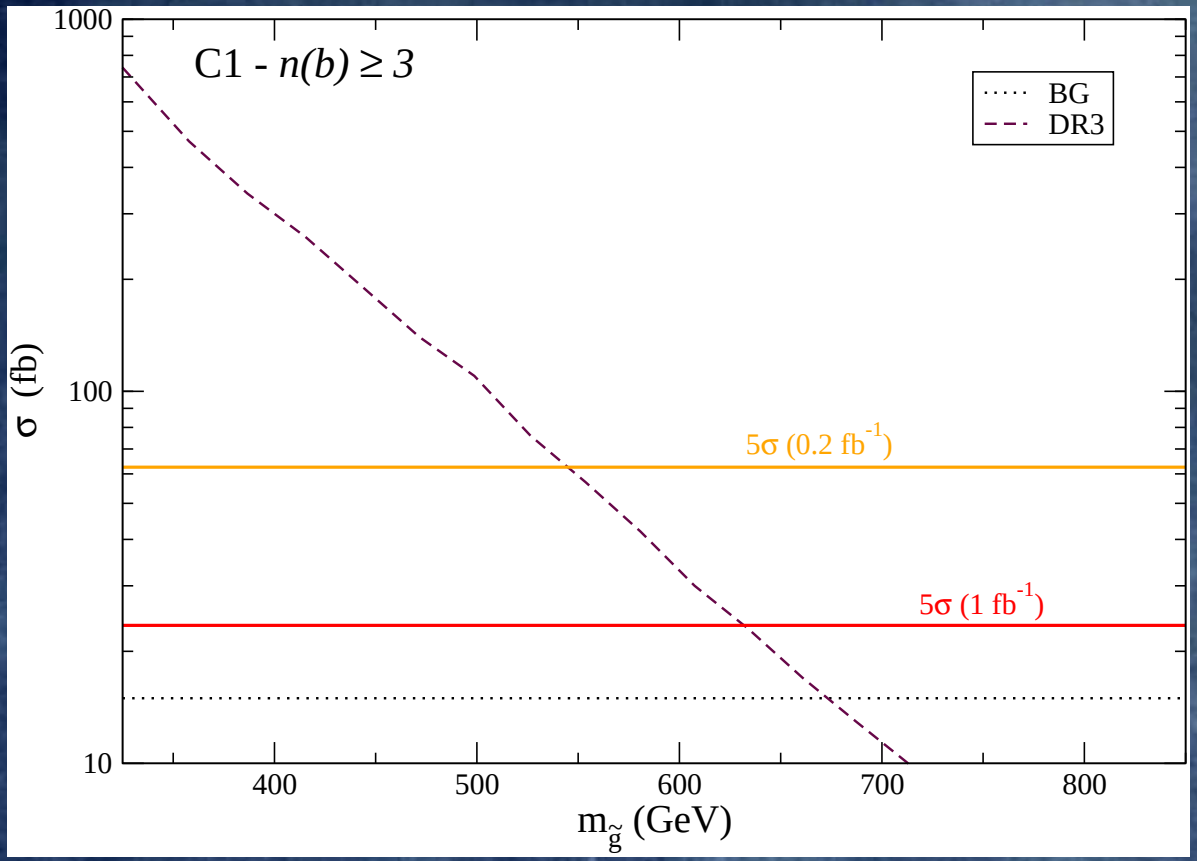
  $m_{\tilde{g}} = 321$ GeV, $m_{\widetilde{W}_1} = 115$ GeV,
  $m_{\widetilde{Z}_2} = 114$ GeV,
  $m_{\widetilde{Z}_1} = 47$ GeV, $m_h = 129$ GeV
  $m_{\tilde{t}_1} = 2.4$ TeV, $m_{\tilde{b}_1} = 1.4$ TeV





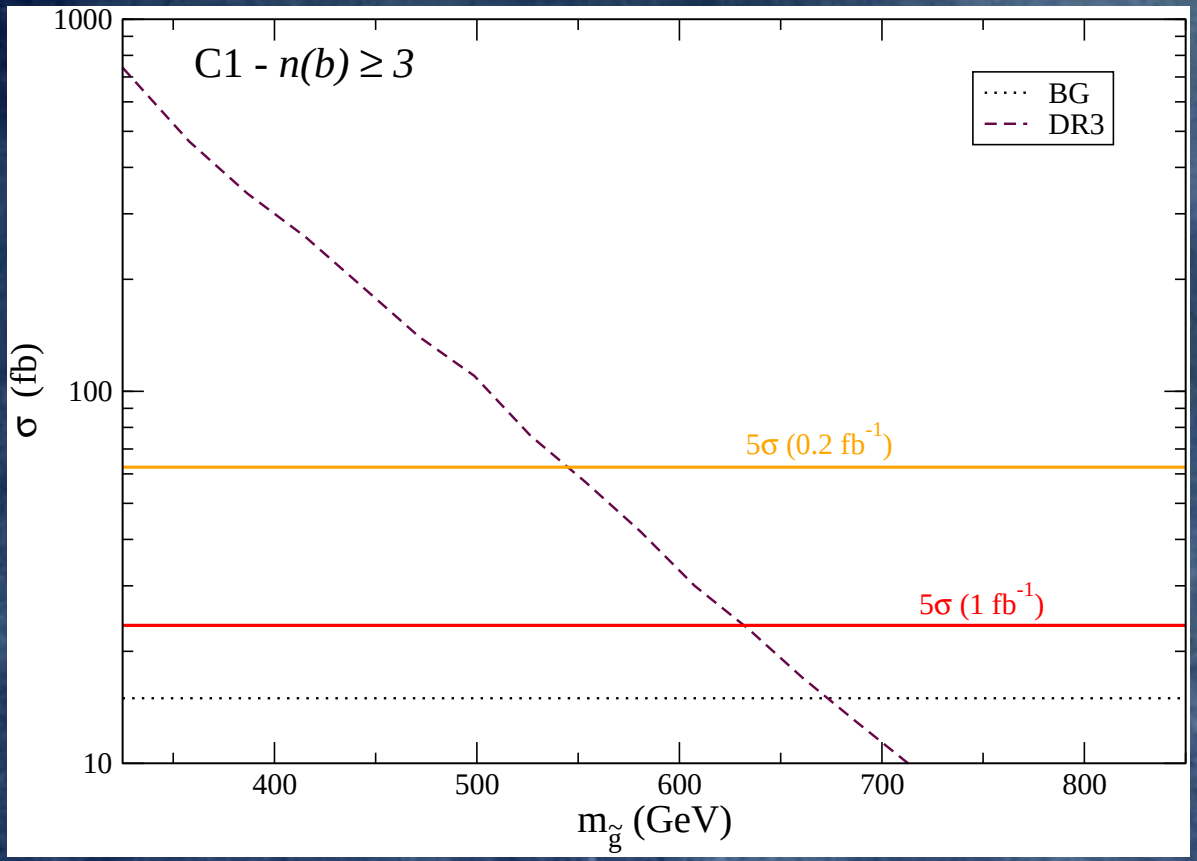


DR3 Reach



$m_{\tilde{g}} \lesssim 650$ GeV

DR3 Reach



$m_{\tilde{g}} \lesssim 650$ GeV

⇒ Once again agrees with estimated reach!

Side Note - MSSM Higgs

- Most likely LHC7 will not be able to discover a light SM Higgs
  - $m_h \lesssim 150$ GeV $\rightarrow h \rightarrow b\bar{b}$ (HUGE Background)

Side Note - MSSM Higgs

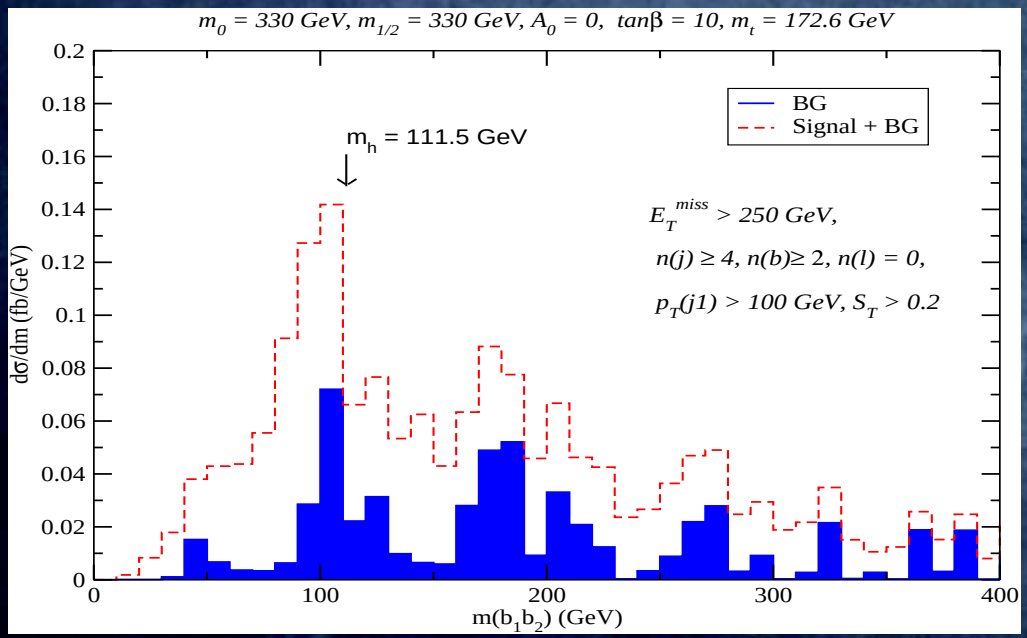
- Most likely LHC7 will not be able to discover a light SM Higgs
  - $m_h \lesssim 150$ GeV $\rightarrow h \rightarrow b\bar{b}$ (HUGE Background)
- However... if h is produced in susy cascade decays:

  $h + \widetilde{Z}_1 \rightarrow b\bar{b} + \not{E}_T$ (small BG)

Side Note - MSSM Higgs

- Most likely LHC7 will not be able to discover a light SM Higgs
  - $m_h \lesssim 150$ GeV $\rightarrow h \rightarrow b\bar{b}$ (HUGE Background)
- However... if h is produced in susy cascade decays:

$h + \widetilde{Z}_1 \rightarrow b\bar{b} + \not{E}_T$ (small BG)

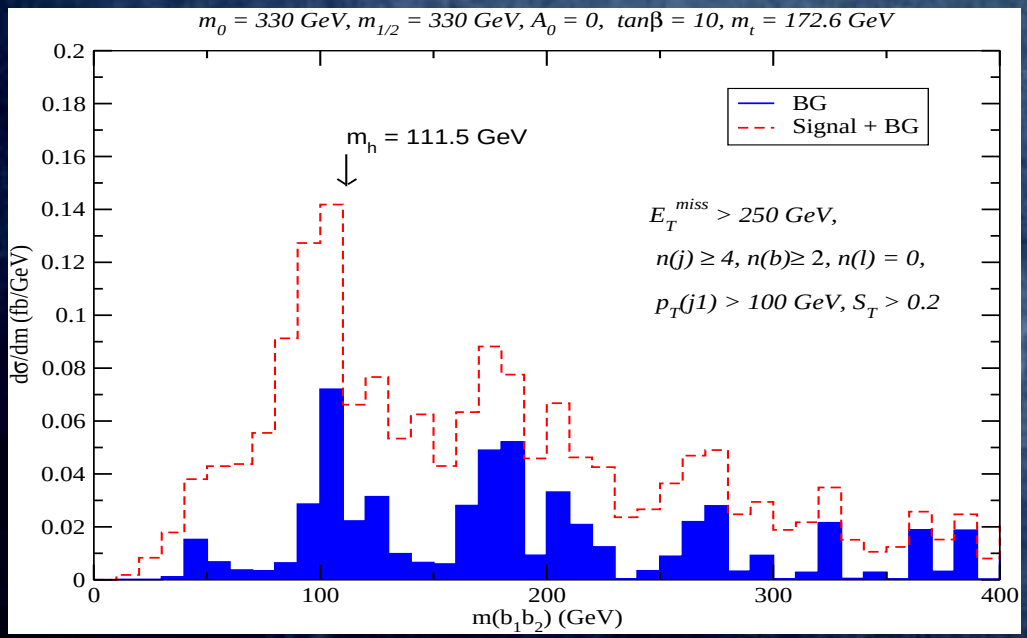


$BF(\widetilde{Z}_2 \rightarrow \widetilde{Z}_1 + h) = 80\ \%$

Side Note - MSSM Higgs

- Most likely LHC7 will not be able to discover a light SM Higgs
  - $m_h \lesssim 150$ GeV $\rightarrow h \rightarrow b\bar{b}$ (HUGE Background)
- However... if h is produced in susy cascade decays:

$h + \widetilde{Z}_1 \rightarrow b\bar{b} + \not{E}_T$ (small BG)



$BF(\widetilde{Z}_2 \rightarrow \widetilde{Z}_1 + h) = 80\ \%$

$\Rightarrow$ Hope?

Conclusions

- LHC7 already has 3 nb^{-1} of data! (or maybe the double by now?)

Conclusions

- LHC7 already has 3 nb^{-1} of data! (or maybe the double by now?)
- Several interesting cases can be excluded:

Conclusions

- LHC7 already has 3 nb^{-1} of data! (or maybe the double by now?)
- Several interesting cases can be excluded:
  - Low fine-tunning, Best fits, SO(10) Yukawa unified

Conclusions

- LHC7 already has 3 nb^{-1} of data! (or maybe the double by now?)
- Several interesting cases can be excluded:
  - Low fine-tunning, Best fits, SO(10) Yukawa unified
- Most of the focus point region will not be acessible ($m_{\tilde{g}} \lesssim 650$ GeV) (probed by Xenon100)

Conclusions

- LHC7 already has 3 nB^{-1} of data! (or maybe the double by now?)
- Several interesting cases can be excluded:
  - Low fine-tunning, Best fits, SO(10) Yukawa unified
- Most of the focus point region will not be acessible ($m_{\tilde{g}} \lesssim 650$ GeV) (probed by Xenon100)
- The first signal should appear in a hadronic channel (jets + $\not{E}_T$ or b-jets + $\not{E}_T$)

Conclusions

- LHC7 already has 3 nb^{-1} of data! (or maybe the double by now?)
- Several interesting cases can be excluded:
  - Low fine-tunning, Best fits, SO(10) Yukawa unified
- Most of the focus point region will not be acessible ($m_{\tilde{g}} \lesssim 650$ GeV) (probed by Xenon100)
- The first signal should appear in a hadronic channel (jets + $\not{E}_T$ or b-jets + $\not{E}_T$)
- Complementary multi-lepton and multi-b channels will give a hint of the underlying model

Conclusions

- LHC7 already has 3 nb^{-1} of data! (or maybe the double by now?)
- Several interesting cases can be excluded:
  - Low fine-tunning, Best fits, SO(10) Yukawa unified
- Most of the focus point region will not be acessible ($m_{\tilde{g}} \lesssim 650$ GeV) (probed by Xenon100)
- The first signal should appear in a hadronic channel (jets + $\not{E}_T$ or b-jets + $\not{E}_T$)
- Complementary multi-lepton and multi-b channels will give a hint of the underlying model
- MSSM Higgs might be visible! (if we are lucky)

Conclusions

- LHC7 already has 3 nb^{-1} of data! (or maybe the double by now?)
- Several interesting cases can be excluded:
  - Low fine-tunning, Best fits, SO(10) Yukawa unified
- Most of the focus point region will not be acessible ($m_{\tilde{g}} \lesssim 650$ GeV) (probed by Xenon100)
- The first signal should appear in a hadronic channel (jets + $\not{E}_T$ or b-jets + $\not{E}_T$)
- Complementary multi-lepton and multi-b channels will give a hint of the underlying model
- MSSM Higgs might be visible! (if we are lucky)
- A large portion of parameter space should be probed even in the first run:

Conclusions

- LHC7 already has 3 nb^{-1} of data! (or maybe the double by now?)
- Several interesting cases can be excluded:
  - Low fine-tunning, Best fits, SO(10) Yukawa unified
- Most of the focus point region will not be acessible ($m_{\tilde{g}} \lesssim 650$ GeV) (probed by Xenon100)
- The first signal should appear in a hadronic channel (jets + $\not{E}_T$ or b-jets + $\not{E}_T$)
- Complementary multi-lepton and multi-b channels will give a hint of the underlying model
- MSSM Higgs might be visible! (if we are lucky)
- A large portion of parameter space should be probed even in the first run:

Conclusions

- LHC7 already has 3 nb^{-1} of data! (or maybe the double by now?)
- Several interesting cases can be excluded:
  - Low fine-tunning, Best fits, SO(10) Yukawa unified
- Most of the focus point region will not be acessible ($m_{\tilde{g}} \lesssim 650$ GeV) (probed by Xenon100)
- The first signal should appear in a hadronic channel (jets + $\not{E}_T$ or b-jets + $\not{E}_T$)
- Complementary multi-lepton and multi-b channels will give a hint of the underlying model
- MSSM Higgs might be visible! (if we are lucky)
- A large portion of parameter space should be probed even in the first run:

$$650 \text{ GeV} \lesssim m_{\tilde{g}} \lesssim 1.1 \text{ TeV}$$

Conclusions

- LHC7 already has 3 nb^{-1} of data! (or maybe the double by now?)
- Several interesting cases can be excluded:
  - Low fine-tunning, Best fits, SO(10) Yukawa unified
- Most of the focus point region will not be acessible ($m_{\tilde{g}} \lesssim 650$ GeV) (probed by Xenon100)
- The first signal should appear in a hadronic channel (jets + $\not{E}_T$ or b-jets + $\not{E}_T$)
- Complementary multi-lepton and multi-b channels will give a hint of the underlying model
- MSSM Higgs might be visible! (if we are lucky)
- A large portion of parameter space should be probed even in the first run:

$$650 \text{ GeV} \lesssim m_{\tilde{g}} \lesssim 1.1 \text{ TeV}$$

$\Rightarrow$ Doubles the current (2 fb^{-1}) CDF/D0 bounds!

Thanks!