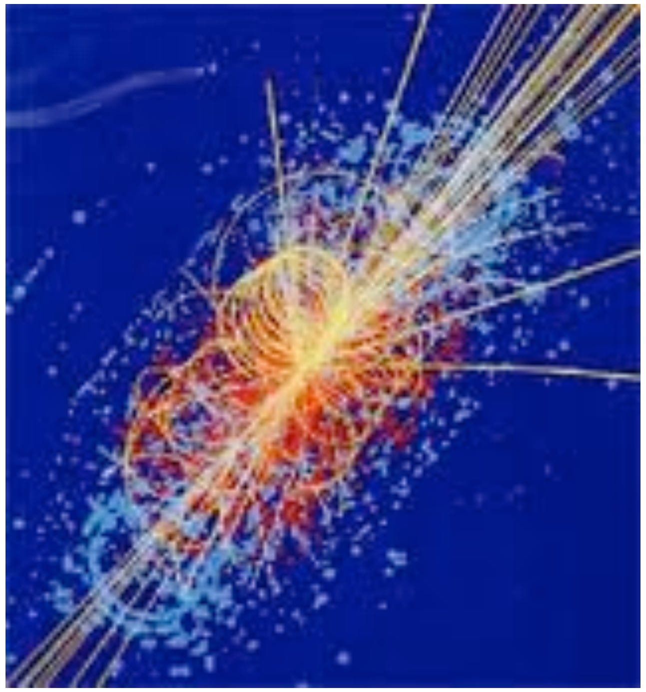
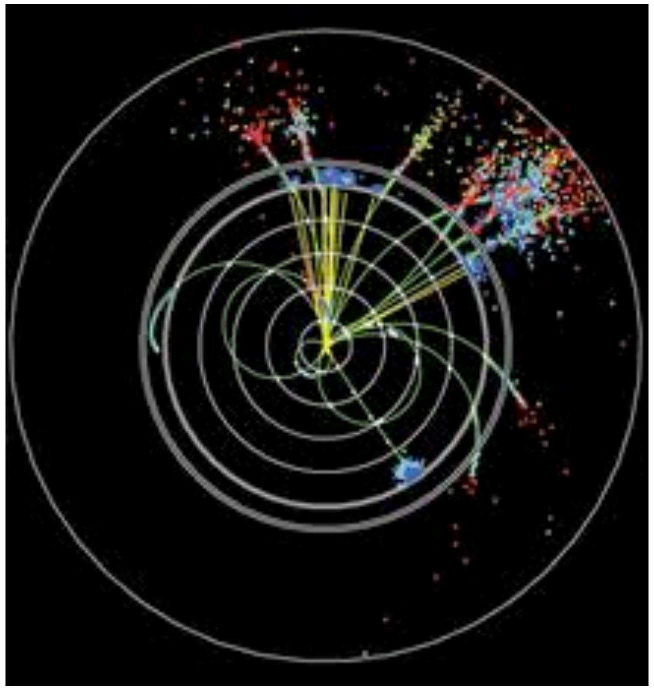
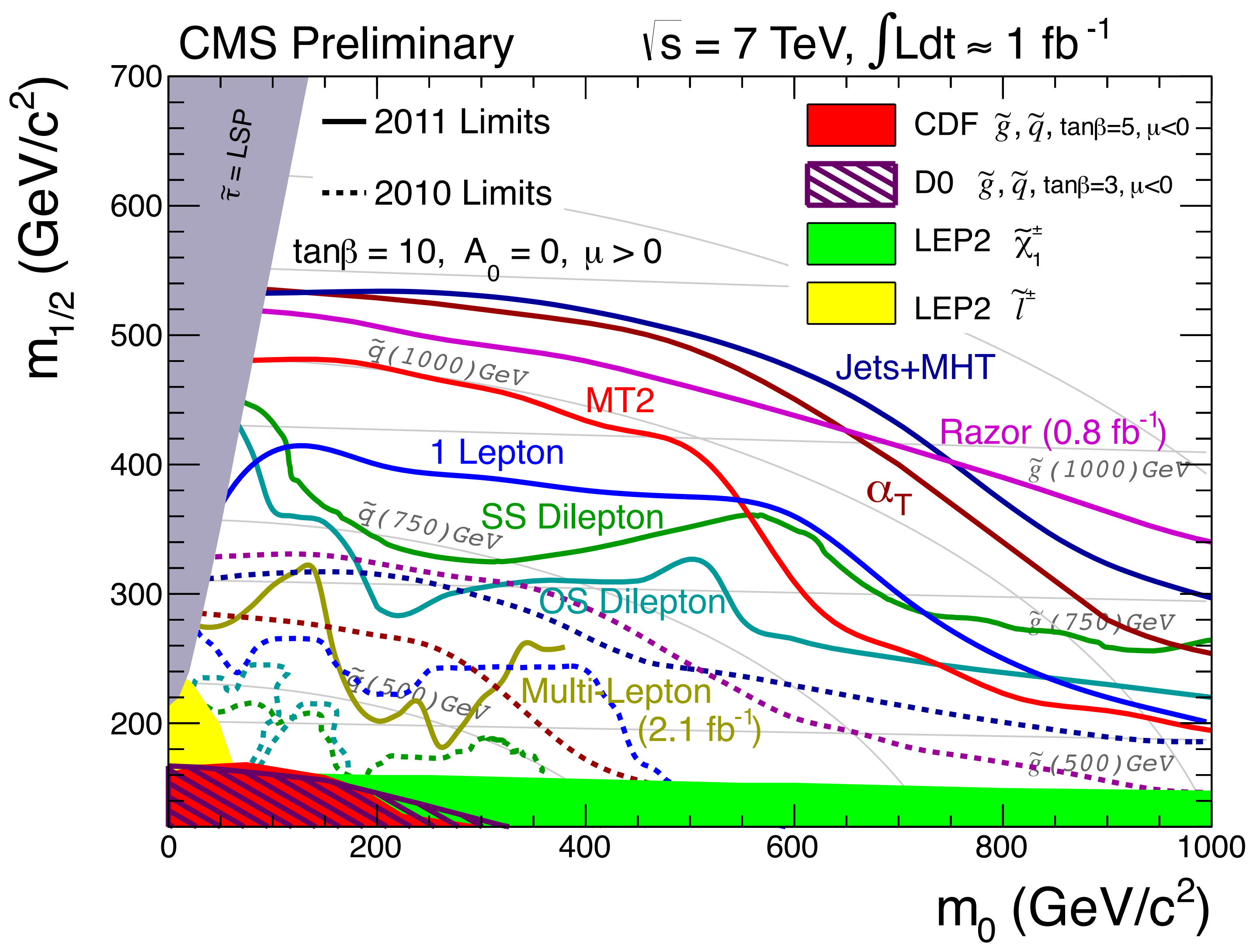
Prospects for SUSY at ILC in light of LHC7

Howie Baer
University of Oklahoma





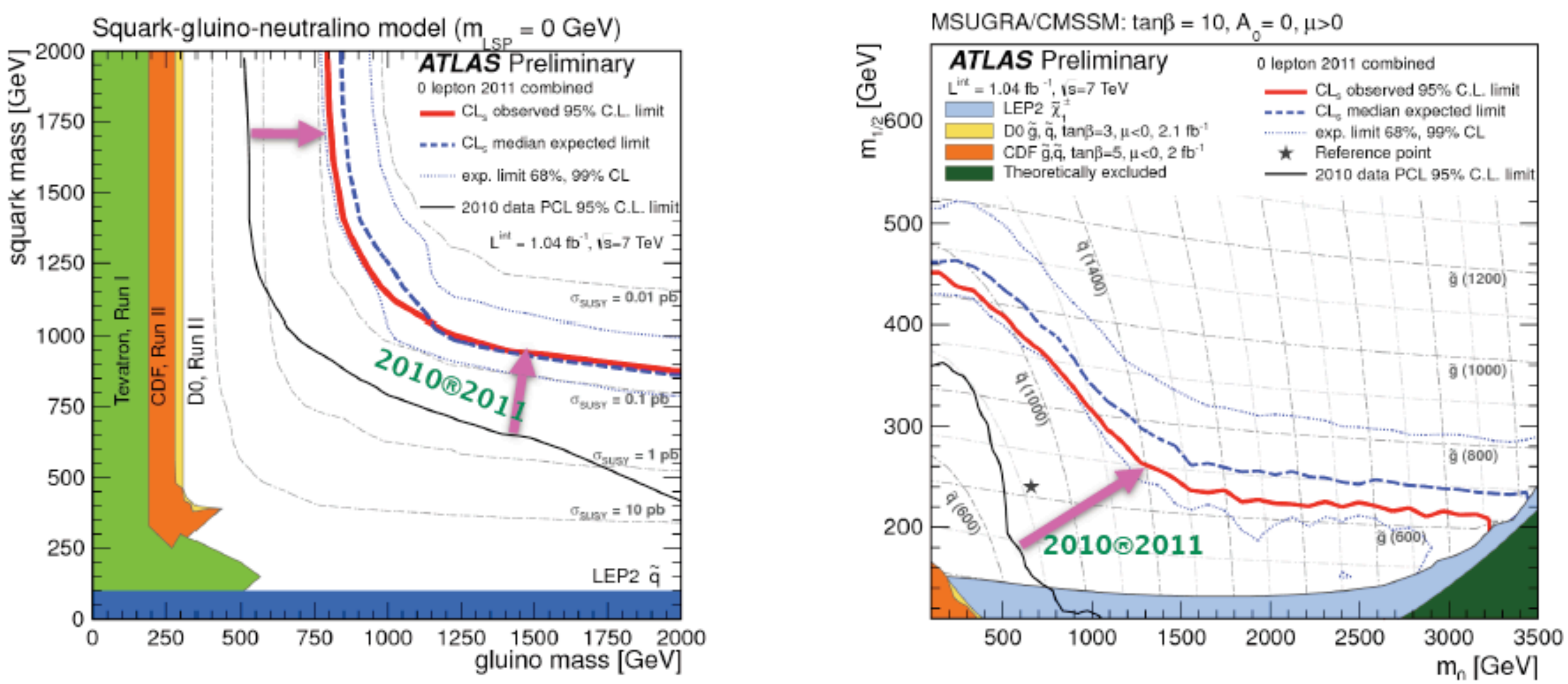
Recent results: CMS with 1 fb^-1



Atlas: 1 fb^-1

0–lepton SUSY exclusion

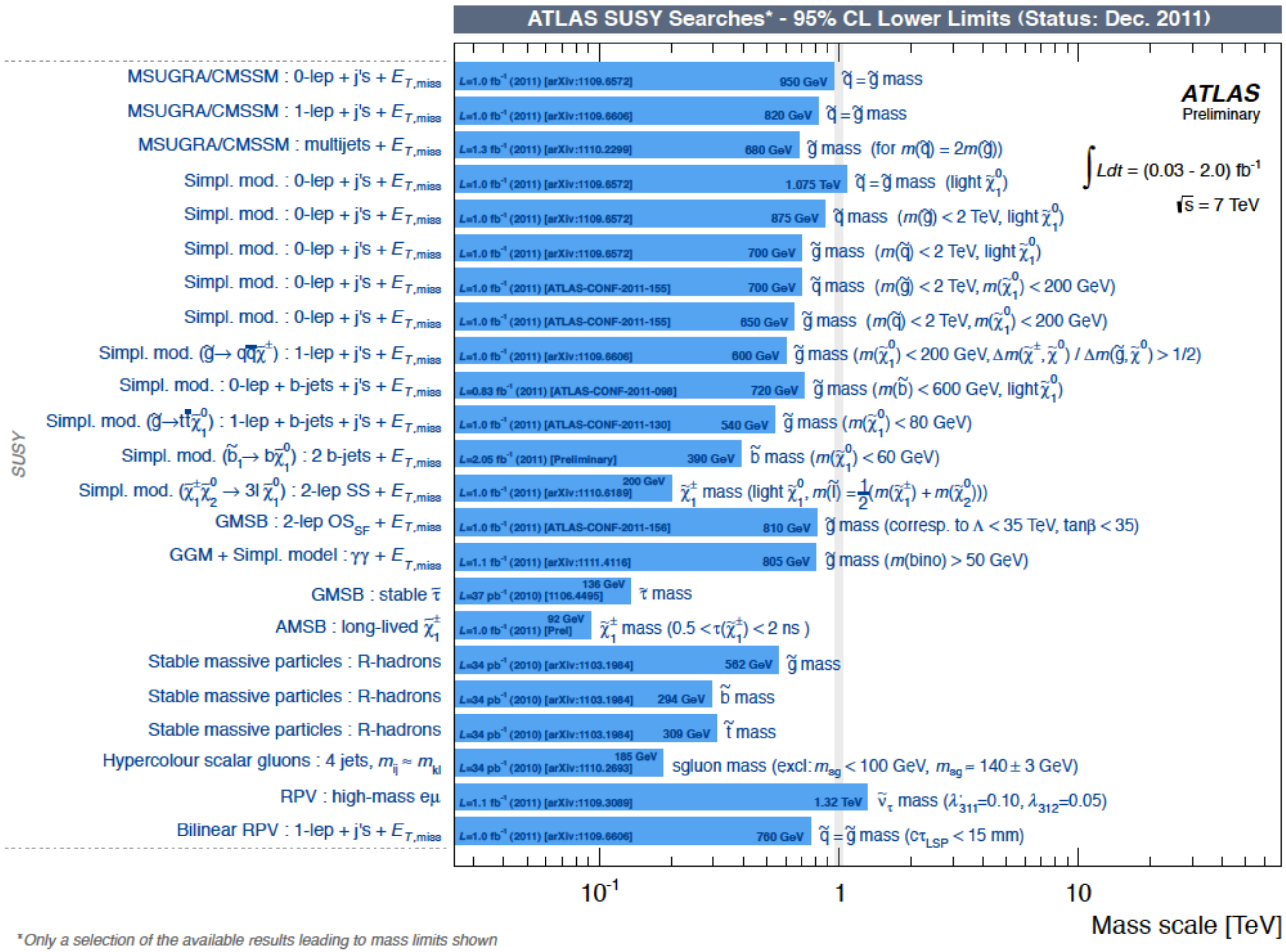
ATLAS preliminary



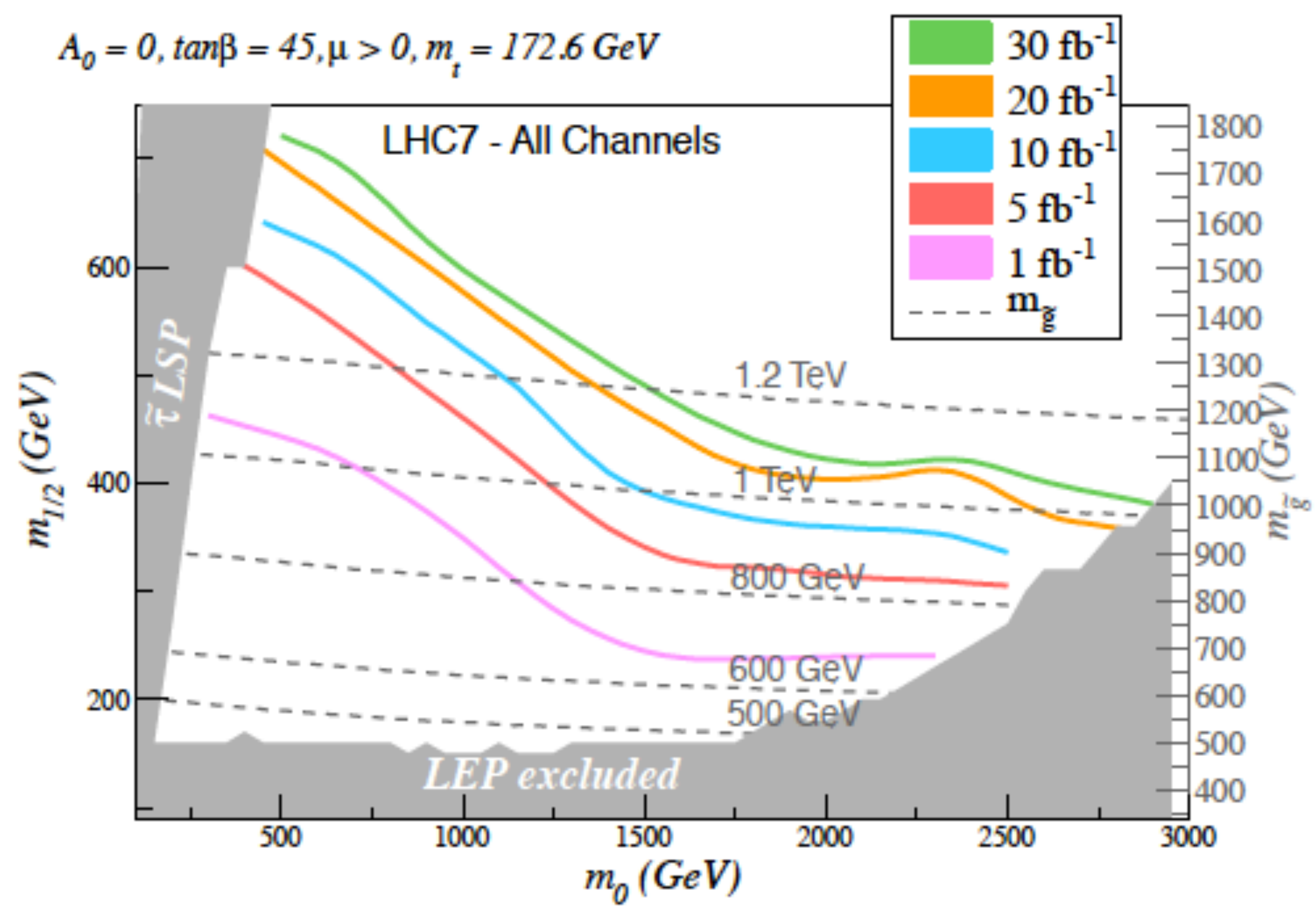
- Data probe squark/gluino cross section of less than 0.1 pb
- Challenging for squark/gluino mass of ~1 TeV

• M_{gluino} > 760 GeV, regardless of squark mass • M_{gluino} = M_{squark} > 1075 GeV	"Simplified model" (left)
• M_{gluino} = M_{squark} > 980 GeV	CMSSM/MSUGRA

No sign of SUSY but new limits for numerous SUSY models



What can we look forward to from LHC in coming year?



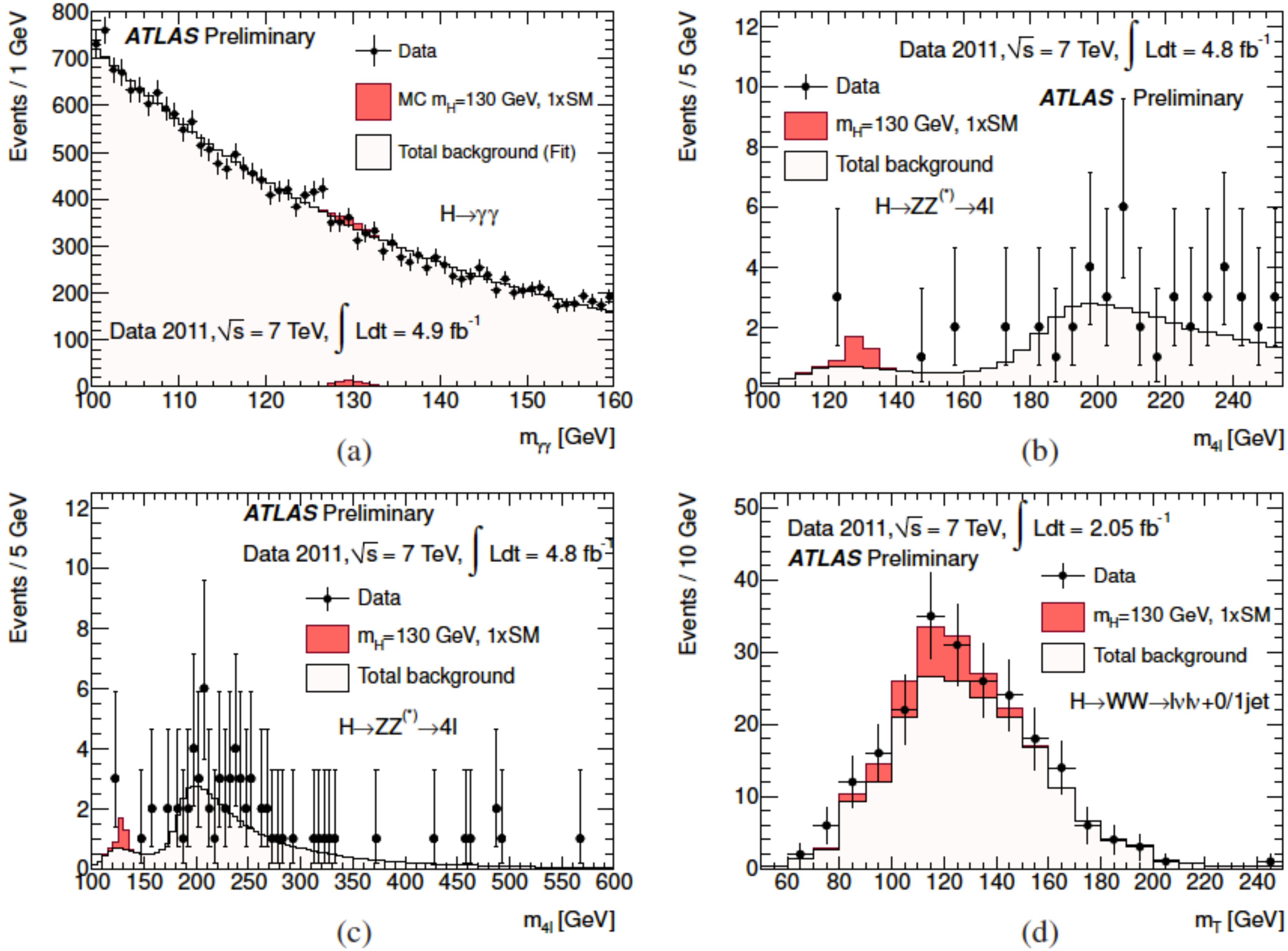
HB,Barger
Lessa,Tata
5 sigma reach
hyper-cuts

For 20 fb^-1:

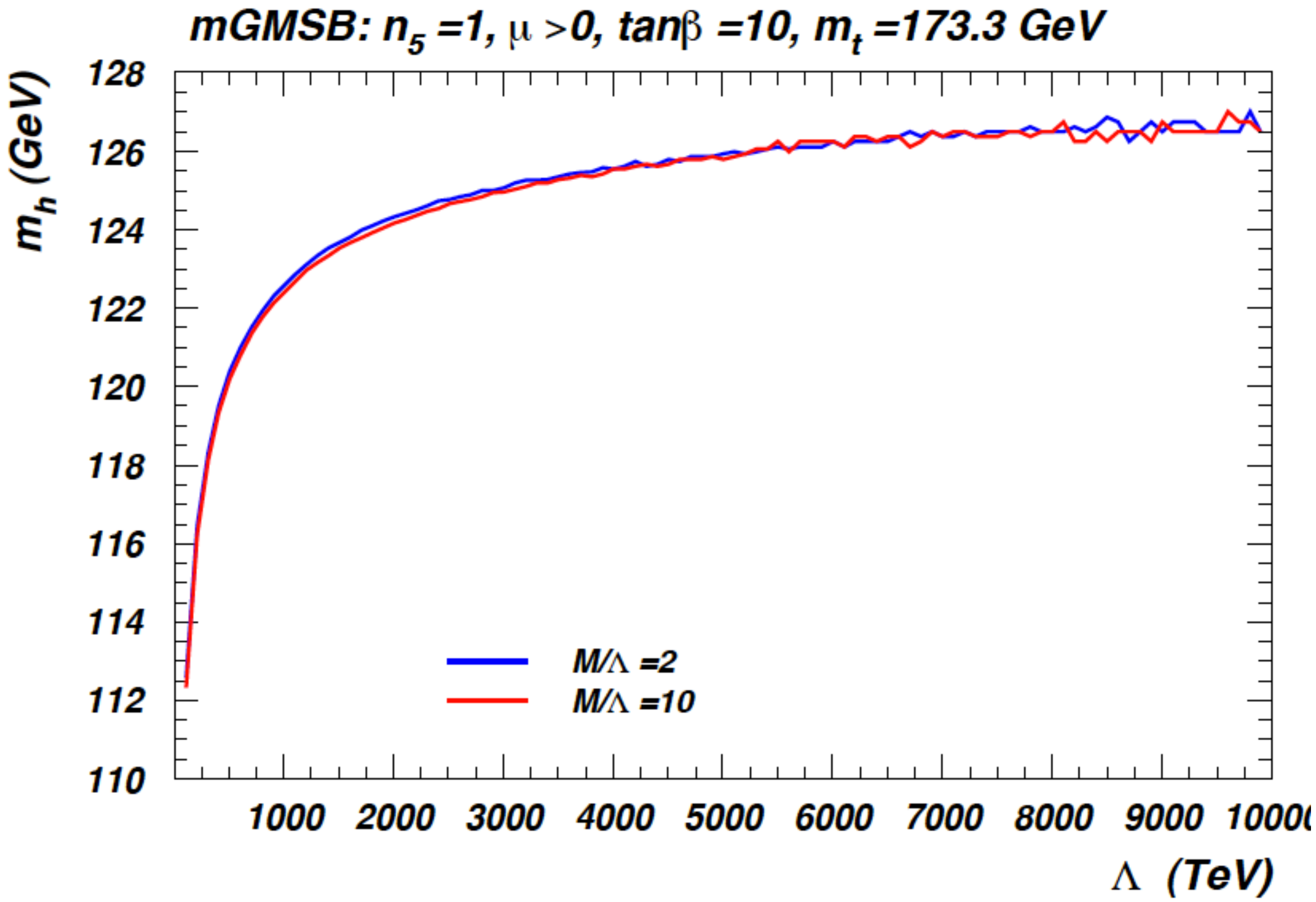
reach to m(gl)~1.5 TeV for msq~mgl

reach to m(gl)~1 TeV for msq>>mgl

Possible Higgs signal at 125 GeV?



Implications for mGMSB



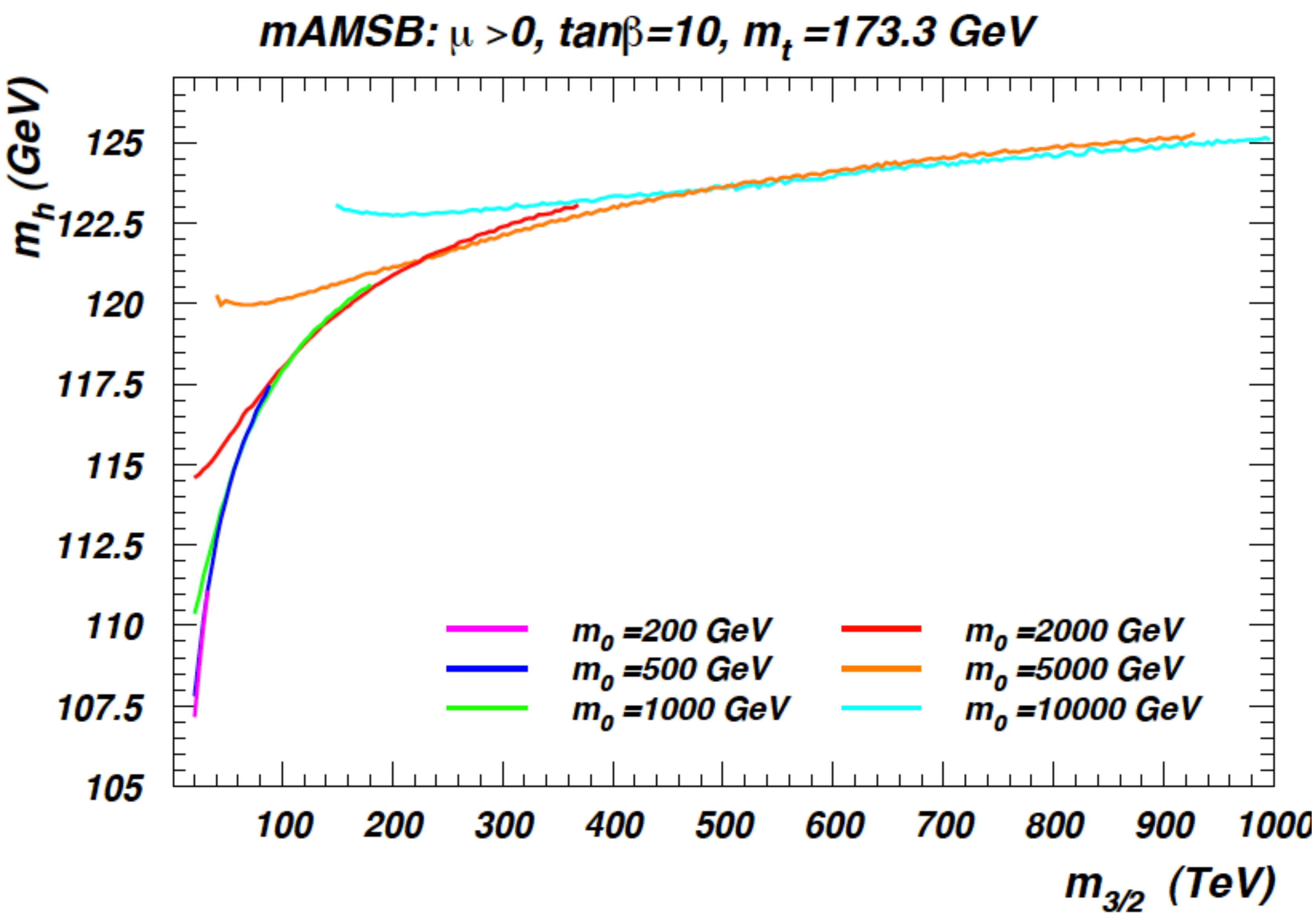
m(gluino)=18.6 TeV

m(chargino)=7.3 TeV

Move to general or non-minimal GMSB?

need large A0

Implications for mAMSB



m(gluino)=14 TeV

m(chargino)=2.2 TeV

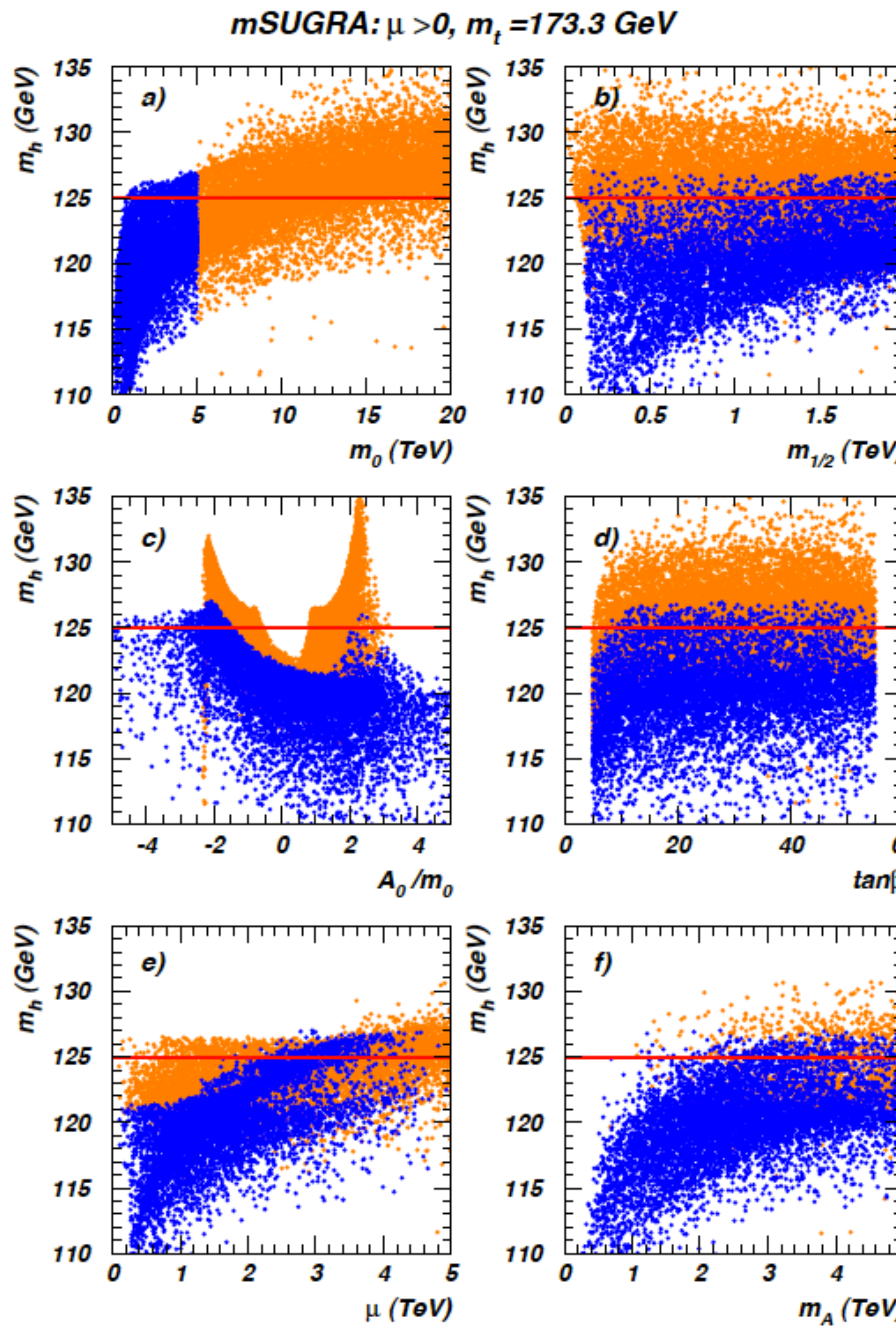
What is left of mSUGRA/CMSSM?

Scan over p-space:

$$m_0 > 1\mathrm{TeV}$$

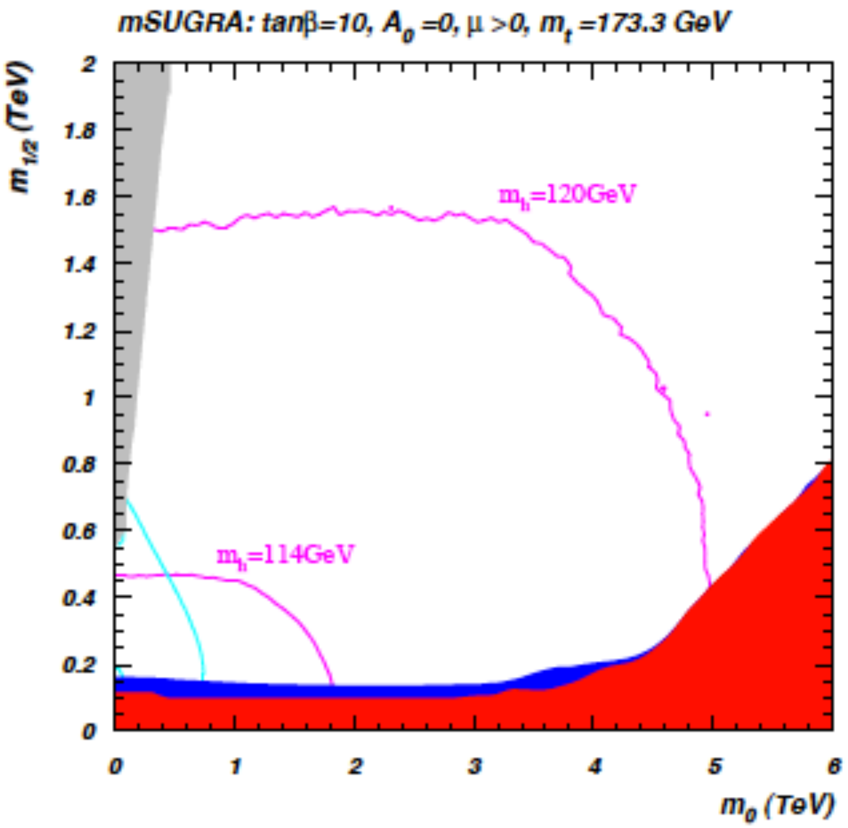
(scalar masses> 1 TeV)

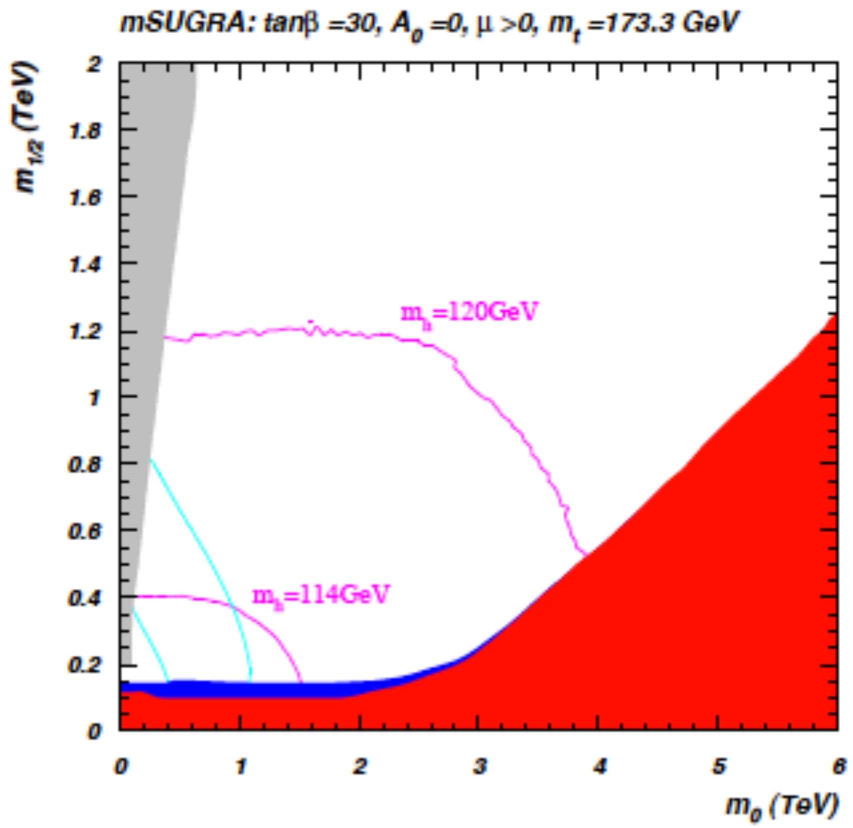
$$|A_0| > 0.5\ \mathrm{TeV}$$



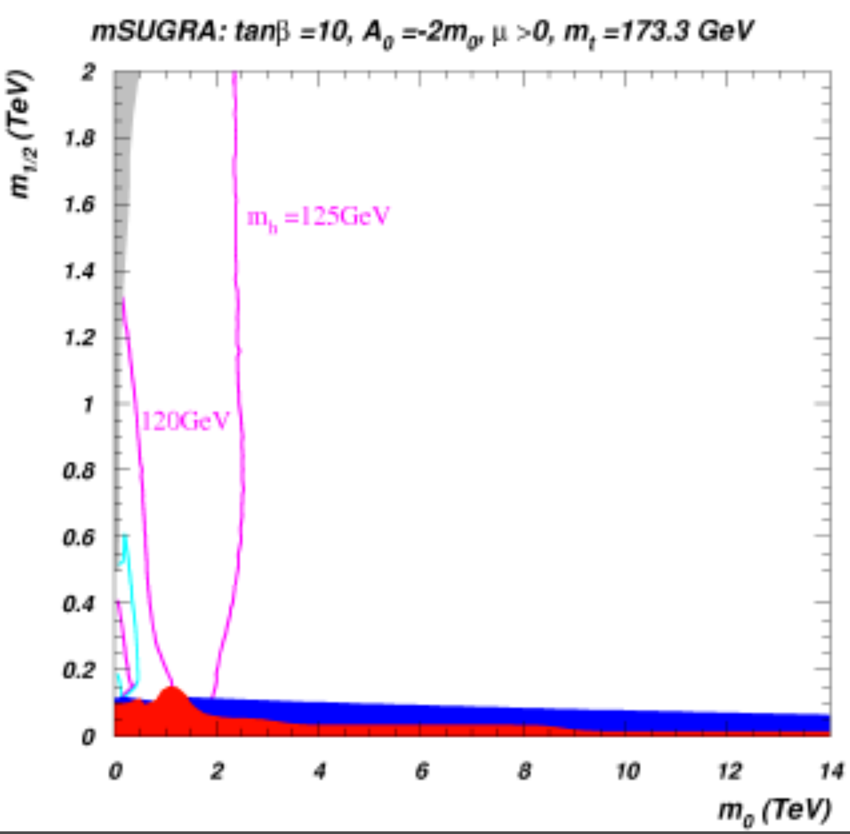
Thermally -produced neutralino CDM: unlikely unless in FP region which has moved out to 10-20 TeV

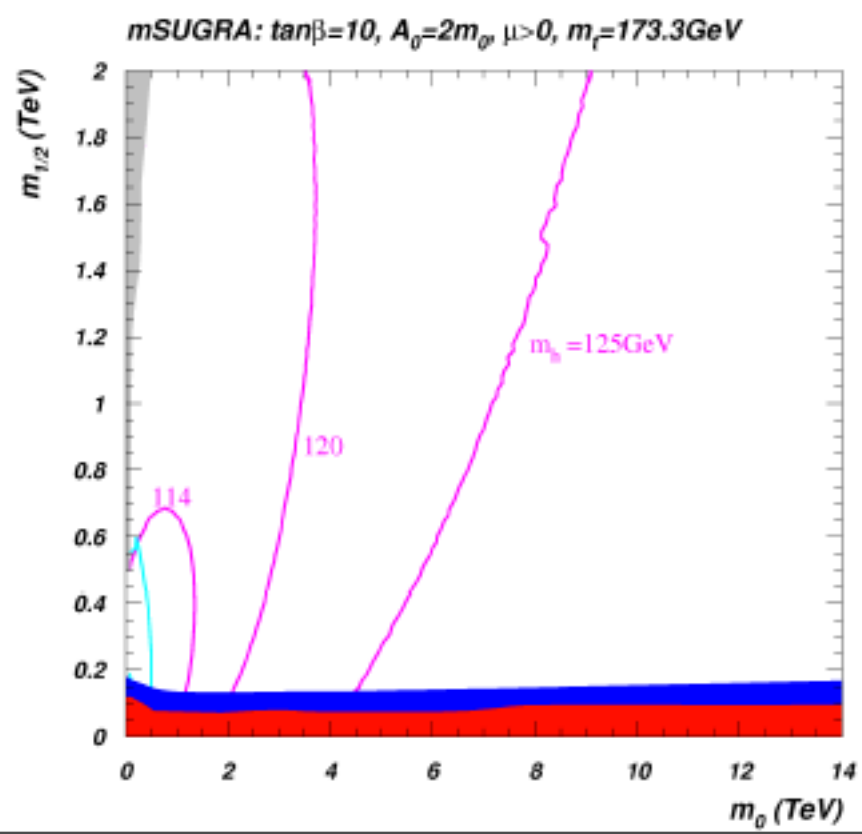
mSUGRA parameter planes





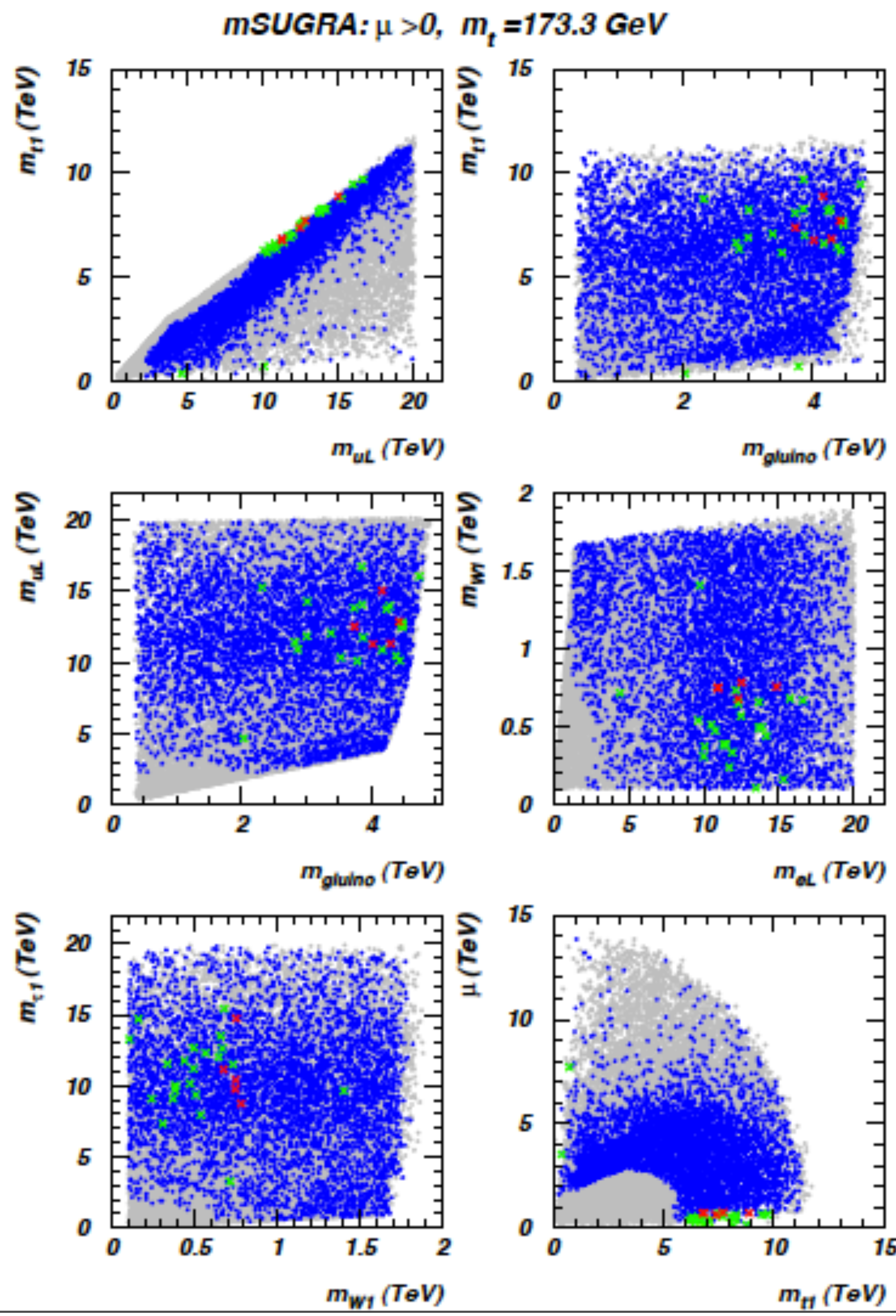
These are excluded if mh~125 GeV!





These are allowed, but m0 is now large

Chargino or stau may still be within ILC reach, but not at same time



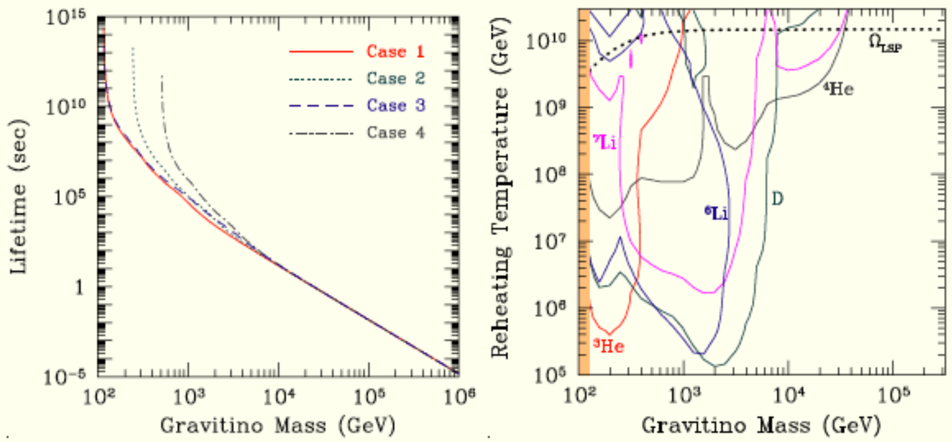
Should we be alarmed?

- To a large extent, these LHC results have been anticipated by many SUSY theorists
- Well-known result: general gravity mediation leads to large FCNC/CP violation: in fact, this was a major motivation for GMSB/AMSB
- good reason for universality within a generation: SO(10)
- no good reason for generational universality within gravity mediation: why CMSSM is a lacking as name for model: forgets about gravitino
- Decoupling solution to mSUGRA flavor/CP/p-decay/gravitino problem: 1st/ 2nd gen. scalars should be in the 10-40 TeV regime (along with gravitino)!
- Gauginos/3rd gen. squarks can be much lighter: sub-TeV
- What about SUSY dark matter?

Three problems with neutralino-only CDM picture

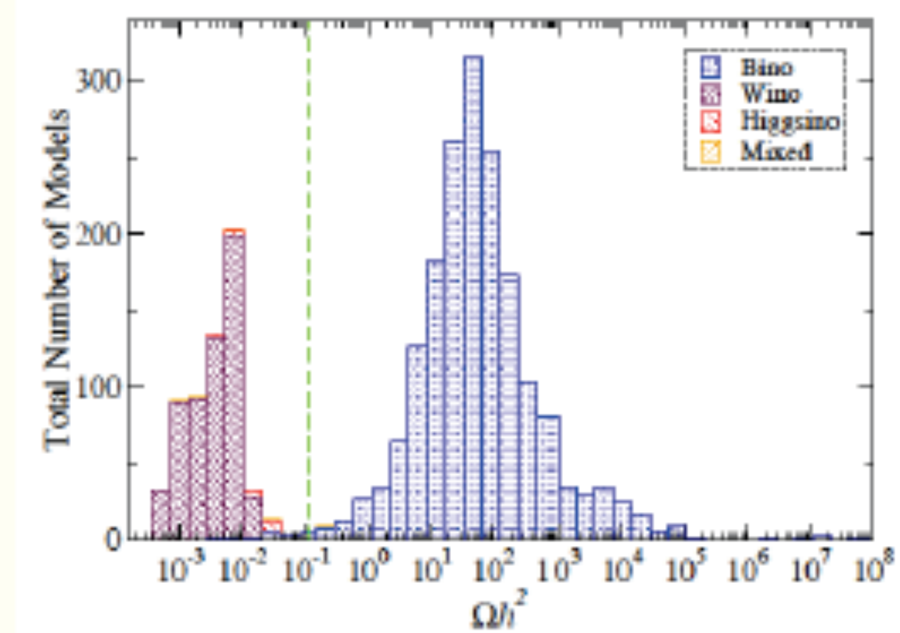
Gravitinos: spin-$\frac{3}{2}$ partner of graviton

- gravitino problem in generic SUGRA models: overproduction of $\tilde{G}$ followed by late $\tilde{G}$ decay can destroy successful BBN predictions unless $T_R \lesssim 10^5$ GeV



(see Kawasaki, Kohri, Moroi, Yotsuyanagi; Cybert, Ellis, Fields, Olive; Jedamzik)

- histogram of models vs. $\Omega_{\tilde{Z}_1} h^2$ with $m_{\tilde{Z}_1} < 500$ GeV



WIMP non-miracle:
HB, Box, Summy

gravitino problem:
need for heavy grav'ino

strong CP problem
and axions

★ Generate additional term to QCD Lagrangian: $\mathcal{L} \ni \theta \frac{g_s^2}{32\pi} F_A^{\mu\nu} \tilde{F}_{A\mu\nu}$

- violates P and T; conserves C

★ In addition, weak interactions $\Rightarrow \mathcal{L} \ni Arg\ det M \frac{g_s^2}{32\pi} F_A^{\mu\nu} \tilde{F}_{A\mu\nu}$

- $\bar{\theta} = \theta + Arg\ det M$

★ experiment: neutron EDM $\Rightarrow \bar{\theta} \lesssim 10^{-10}$

★ How can this be? The strong CP problem

Alternative cosmologies: more compelling and possibly compulsory

- Late decaying scalar (moduli) field(s): enhance relic abundance or entropy dilution (Kane theorem: must have one)
- PQ augmented MSSM: axion, saxion, axino all contribute to enhance/dilute relic abundance: in this case, mixed axion/LSP CDM where LSP=neutralino, axino or gravitino
- Old Omega h^2 constraint not solid

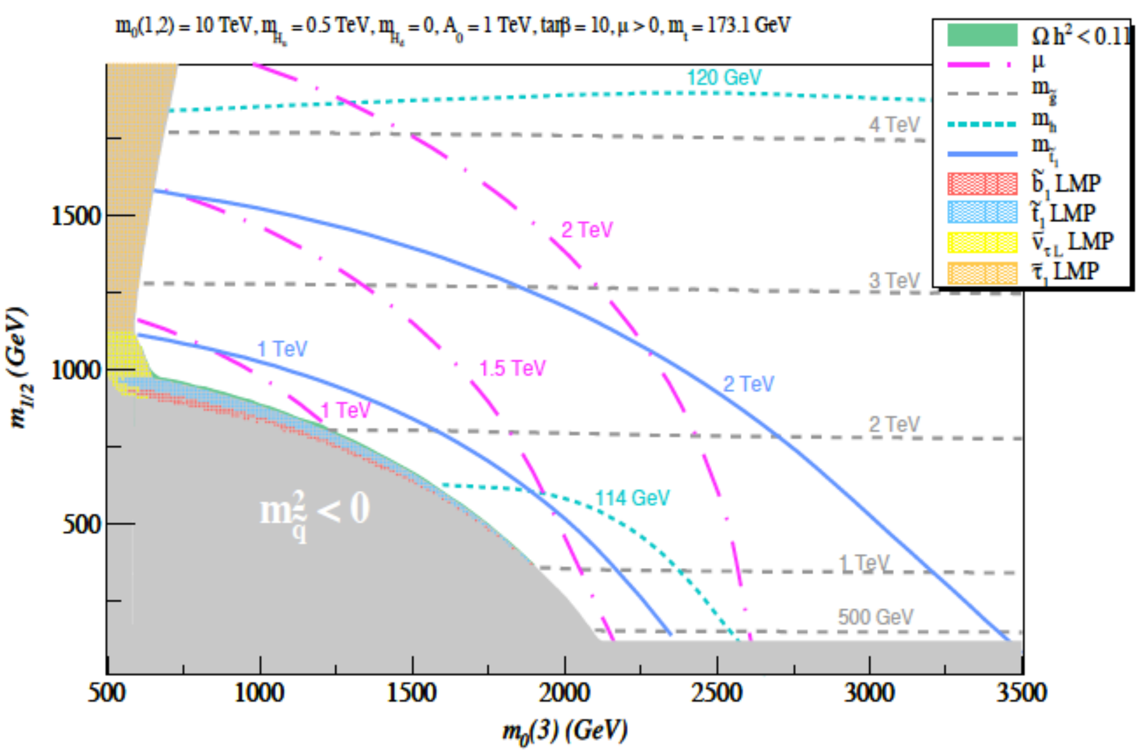
Some compelling models of interest to ILC searches

- effective SUSY
- hidden SUSY (small mu)
- natural SUSY
- Yukawa-unified SUSY
- mirage mediation (compressed)
- normal mass hierarchy
- NMSSM (talk by Kraml)
- RPV SUSY (talk by Vormwald)

Effective SUSY

Cohen, Kaplan, Nelson

- Multi-TeV 1st/2nd gen. scalars to solve SUSY flavor/CP problem
- Sub-TeV 3rd gen. scalars for acceptable finetuning



HB, Kraml, Lessa, Sekmen, Tata

parameter	ES3
$m_0(1,2)$ [TeV]	10
$m_0(3)$ [TeV]	1.1
m_{H_d} [TeV]	−0.6
m_{H_u} [TeV]	0.5
$m_{1/2}$ [TeV]	0.85
A_0 [TeV]	1
μ	925
$m_{\tilde{g}}$	2103
$m_{\tilde{u}_L}$ [TeV]	10.1
$m_{\tilde{u}_R}$ [TeV]	10.1
$m_{\tilde{e}_L}$ [TeV]	10.0
$m_{\tilde{e}_R}$ [TeV]	10.0
$m_{\tilde{t}_1}$	398
$m_{\tilde{t}_2}$	770
$m_{\tilde{b}_1}$	586
$m_{\tilde{b}_2}$	958
$m_{\tilde{\tau}_1}$	944
$m_{\tilde{\tau}_2}$	1008
$m_{\widetilde{W}_1}$	708
$m_{\tilde{Z}_2}$	708
$m_{\tilde{Z}_1}$	372
m_A	398

Hidden SUSY

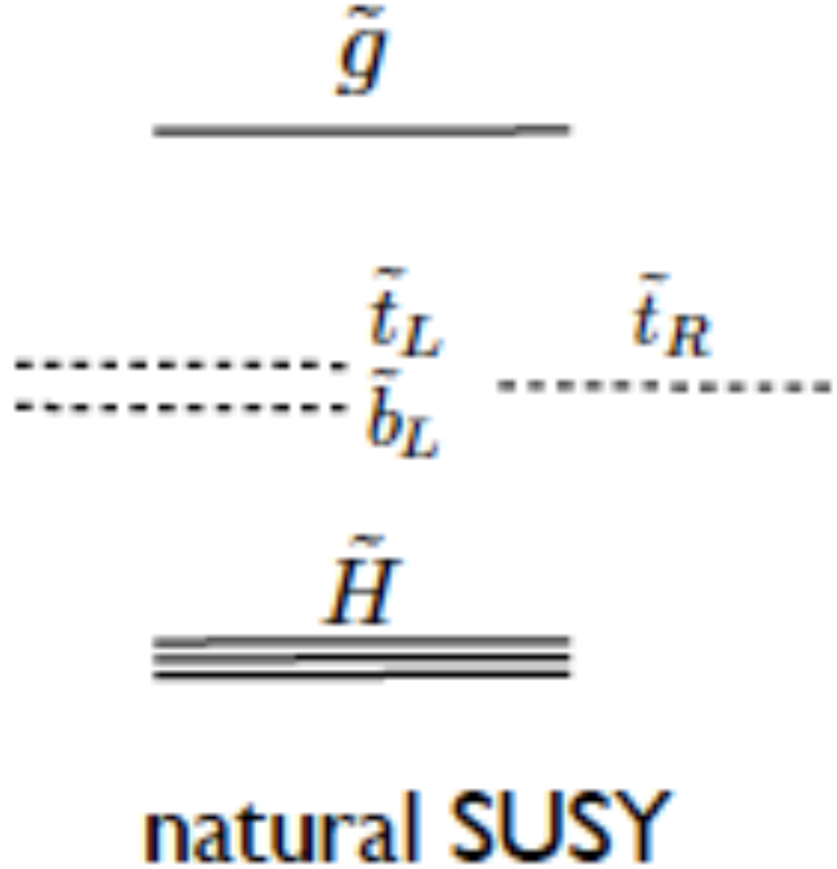
- superpotential mu parameter itself is measure of fine tuning (Chan, Chattopadyay,Nath)
- scenario where all soft terms heavy but small mu
- light higgsino-like Z1, Z2, W1, but with small mass gap mw1-mz1, mz2-mz1
- escape detection at LHC but can do at ILC

parameter	HW150
m_0	5000
$m_{1/2}$	800
A_0	0
$\tan\beta$	10
μ	150
m_A	800
$m_{\tilde{g}}$	2004.9
$m_{\tilde{u}_L}$	5171.5
$m_{\tilde{t}_1}$	3240.2
$m_{\tilde{b}_1}$	4267.8
$m_{\tilde{e}_R}$	4869.4
$m_{\widetilde{W}_2}$	672.7
$m_{\widetilde{W}_1}$	156.3
$m_{\widetilde{Z}_4}$	688.2
$m_{\widetilde{Z}_3}$	356.3
$m_{\widetilde{Z}_2}$	158.9
$m_{\widetilde{Z}_1}$	142.7
m_h	120.1

Cheung, Chiang, Song
HB, Barger, Huang

Natural SUSY

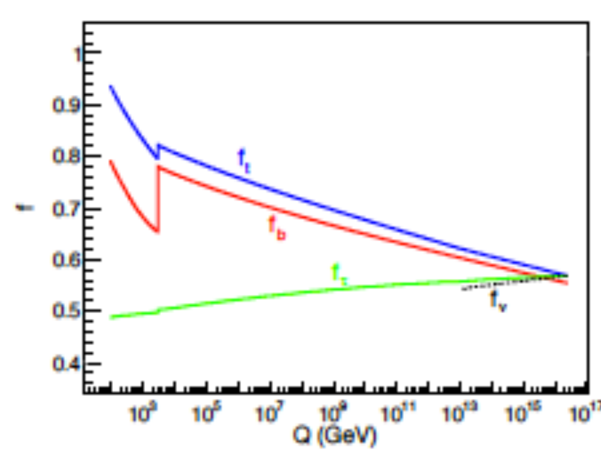
- mu~mh(125)
- t1,t2,b1,b2 <500 GeV
- qL,qR~10-20 TeV
- gluino~1500 GeV
- Arkani-Hamed;
- Papucci et al.;
- Brust et al.;
- Essig et al.



Yukawa unified SUSY

- unification of forces
- unification of matter into 16 of SO(10)
- unification of t-b-tau Yukawa couplings
- spectra in radiatively driven inverted scalar mass hierarchy with tan(beta)~50

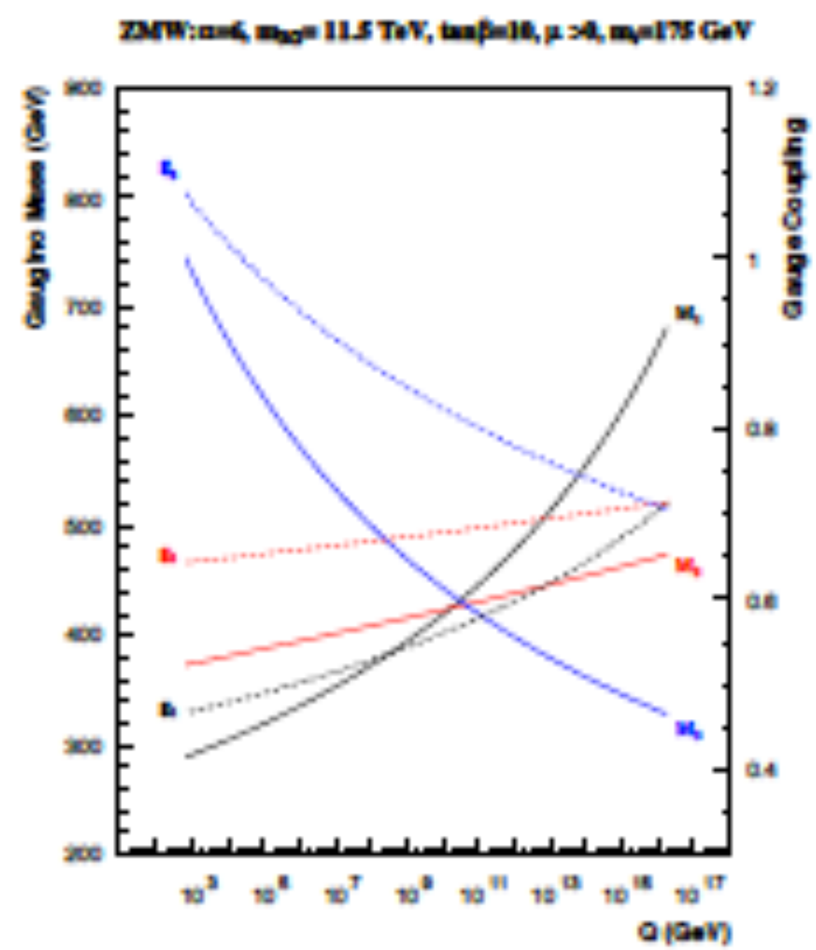
	Point 1
m_{16}	21370
$m_{1/2}$	93.41
A_0/m_{16}	-2.43
$\tan\beta$	57.2
m_{H_d}	22500.0
m_{H_u}	13310.0
m_h	126.7
m_H	9389
m_A	9328
$m_{H^\pm}$	9390
$m_{\tilde{g}}$	750
$m_{\tilde{\chi}^0_{1,2}}$	122, 285
$m_{\tilde{\chi}^0_{3,4}}$	19295, 19295
$m_{\tilde{\chi}^\pm_{1,2}}$	286, 19330
$m_{\tilde{u}_{L,R}}$	21389,21132
$m_{\tilde{t}_{1,2}}$	7389,8175
$m_{\tilde{d}_{L,R}}$	21389,21513
$m_{\tilde{b}_{1,2}}$	7836,8234
$m_{\tilde{\nu}_1}$	21196
$m_{\tilde{\nu}_3}$	15502
$m_{\tilde{e}_{L,R}}$	21193,21717
$m_{\tilde{\tau}_{1,2}}$	7490,15463
$\Omega_{CDM}h^2$	12642
R_{tbr}	1.06



HB, Kraml,Sekmen
HB, Raza,Shafi

Mirage unification (mixed moduli-AMSB)

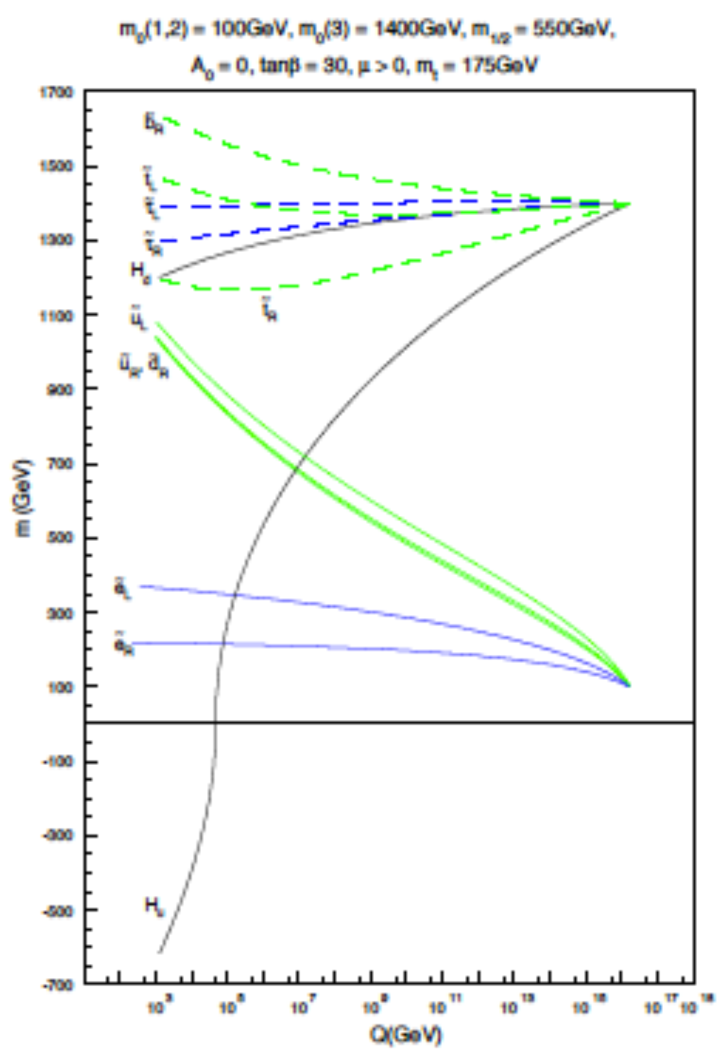
- Based on KKLT string models with moduli stabilization and uplifted potential
- Soft terms are combination of AMSB and gravity-mediation: mixing parameter alpha
- Gaugino masses unify at intermediate ``mirage" scale
- Compressed spectra difficult at LHC



Model line 9 in Isasugra/Isajet

What about (g-2)_mu: Normal scalar mass hierarchy

- (g-2)_mu needs light smuons
- BF(b->s gamma) needs heavy stops
- NMH model: m0(1)=m0(2)<<m0(3)



HB, Belyaev,
Krupovnickas,Mustafayev

parameter	value (GeV)
M_2	351.1
s[41]. M_1	184.2
μ	516.9
$m_{\tilde{g}}$	1067.7
$m_{\tilde{u}_L}$	939.8
$m_{\tilde{u}_R}$	910.0
$m_{\tilde{d}_L}$	943.5
$m_{\tilde{d}_R}$	907.1
$m_{\tilde{t}_1}$	1175.1
$m_{\tilde{t}_2}$	1477.5
$m_{\tilde{b}_1}$	1460.0
$m_{\tilde{b}_2}$	1637.1
$m_{\tilde{e}_L}$	319.3
$m_{\tilde{e}_R}$	188.2
$m_{\tilde{\nu}_e}$	295.1
$m_{\tilde{\tau}_1}$	1386.1
$m_{\tilde{\tau}_2}$	1475.4
$m_{\tilde{\nu}_\tau}$	1468.5
$m_{\widetilde{W}_1}$	348.2
$m_{\widetilde{W}_2}$	542.4
$m_{\widetilde{Z}_1}$	179.4
$m_{\widetilde{Z}_2}$	347.2
m_A	1379.3
m_h	118.4
$\Omega_{\widetilde{Z}_1}h^2$	0.115
$BF(b \to s\gamma)$	3.52×10^{-4}
Δa_μ	35.1×10^{-10}

Conclusions

- New LHC SUSY limits appear daunting
- But h(125)- if it persists- can re-inforce: heavy scalars with large A0
- pressure on mAMSB, mGMSB
- SUGRA (min and non-min) survives in lots of guises
- Survey of several compelling models beyond mSUGRA shows that there will likely be a huge role for ILC to play whether or not LHC discovers SUSY