Post-Higgs Discovery SUSY Fits

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Orsay, 11/2011

based on collaboration with

O. Buchmüller, R. Cavanaugh, A. De Roeck, M. Dolan, J. Ellis, H. Flächer, G. Isidori, J. Marrouche, K. Olive, S. Rogerson, F. Ronga, K. de Vries, G. Weiglein

1. SUSY fits with the MasterCode

2. Pre-Higgs results

3. Post-Higgs results

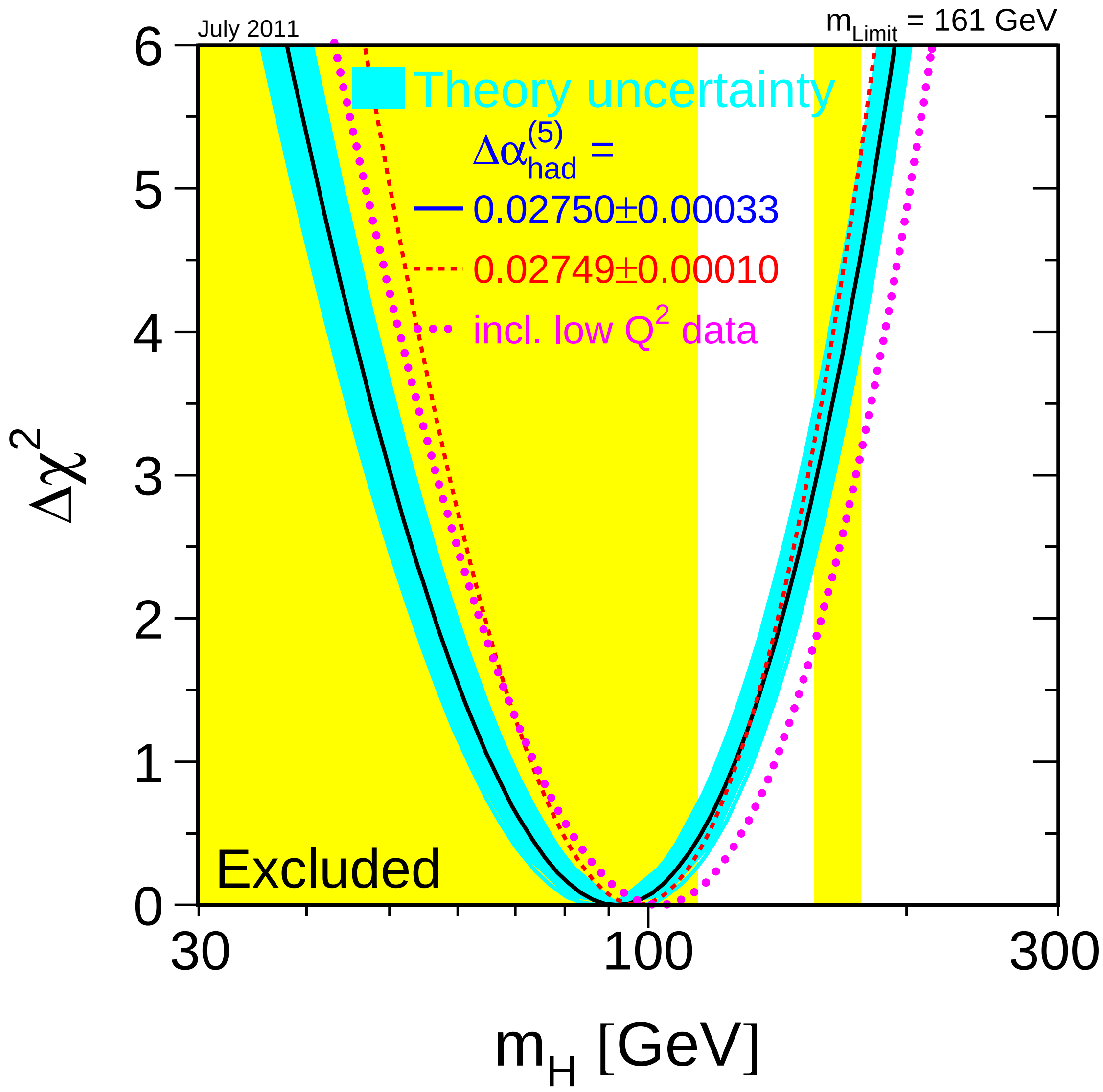
1. SUSY fits with the MasterCode

Global fit to all SM data:

[LEPEWWG '11]

$\Rightarrow M_H = 92^{+34}_{-26}$ GeV

$M_H < 161$ GeV, 95% C.L.



Assumption for the fit:
SM incl. Higgs boson

$\Rightarrow$ no confirmation of
Higgs mechanism

Main idea of the MasterCode: do "the same" in Supersymmetry!

Combine all existing precision data:

- Electroweak precision observables (EWPO)
- B physics observables (BPO)
- Cold dark matter (CDM)
- ...

Predict:

- best-fit points
- ranges for Higgs masses
- ranges for SM parameters
- ranges for SUSY masses $\Rightarrow$ LHC reach

Our tool:

The "MasterCode"

⇒ collaborative effort of theorists and experimentalists

[O. Buchmüller, R. Cavanaugh, D. Colling, A. De Roeck, M. Dolan, J. Ellis, H. Flächer, S.H., G. Isidori, K. Olive, S. Rogerson, F. Ronga, G. Weiglein]

Über-code for the combination of different tools:

- Über-code original in Fortran, now re-written in C++
- tools are included as subroutines
- compatibility ensured by collaboration of authors of "MasterCode" and authors of "sub tools" /SLHA(2)
- sub-codes in Fortran or C++

⇒ evaluate observables of one parameter point consistently with various tools

cern.ch/mastercode

Status of the "MasterCode":

– one model: (MFV) MSSM (see next section)

– tools included:
  – B-physics observables [*SuFla*]
  – more B-physics observables [*SuperIso*]
  – Higgs related observables, $(g-2)_\mu$ [*FeynHiggs*]
  – Electroweak precision observables [*FeynWZ*]
  – Dark Matter observables [*MicrOMEGAs, DarkSUSY*]
  – for GUT scale models: RGE running [*SoftSusy*]

⇒ all most-up-to-date codes on the market!

– added: χ^2 analysis code [*Minuit*]

– currently being implemented:
  – Higgs constraints (for χ^2 contributions ...) [*HiggsBounds*]

– planned: inclusion of more tools / more models

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Indirect constraints on M_{SUSY} from existing data?

- Electroweak precision observables (EWPO) ?
- B physics observables (BPO) ?
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EWPO M_W : information on $m_{\tilde{t}}$, $m_{\tilde{b}}$ or M_A, $\tan\beta$ or ...

EWPO $(g-2)_\mu$: information on $\tan\beta$ and/or $m_{\tilde{\chi}^0}$, $m_{\tilde{\chi}^\pm}$ and/or $m_{\tilde{\mu}}$, $m_{\tilde{\nu}_\mu}$

BPO $\mathrm{BR}(b \to s\gamma)$: information on $\tan\beta$ and/or $M_{H^\pm}$ and/or $m_{\tilde{t}}$, $m_{\tilde{\chi}^\pm}$

CDM (LSP gives CDM) : information on $m_{\tilde{\chi}_1^0}$ and $m_{\tilde{\tau}}$ or M_A or ...

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CDM (LSP gives CDM) : information on $m_{\tilde{\chi}_1^0}$ and $m_{\tilde{\tau}}$ or M_A or ...

$\Rightarrow$ combination makes only sense if all parameters are connected!

$\Rightarrow$ only possible in GUT based models: CMSSM, NUHM1, ...

GUT based models: 1.) CMSSM (sometimes wrongly called mSUGRA):

⇒ Scenario characterized by

$$m_0,\ m_{1/2},\ A_0,\ \tan\beta,\ \text{sign}\,\mu$$

m_0 : universal scalar mass parameter

$m_{1/2}$: universal gaugino mass parameter

A_0 : universal trilinear coupling

} at the GUT scale

$\tan\beta$: ratio of Higgs vacuum expectation values

sign(μ) : sign of supersymmetric Higgs parameter

⇒ particle spectra from renormalization group running to weak scale

⇒ Lightest SUSY particle (LSP) is the lightest neutralino

GUT based models: 2.) NUHM1: (Non-universal Higgs mass model)

Assumption: no unification of scalar fermion and scalar Higgs parameter at the GUT scale

$\Rightarrow$ effectively M_A or μ as free parameters at the EW scale

$\Rightarrow$ besides the CMSSM parameters

M_A or μ

And there is more: 3.) VCMSSM
4.) mSUGRA
5.) NUHM2

. . . no time here . . .

χ^2 calculation:

$\rightarrow$ global χ^2 likelihood function
combines all theoretical predictions with experimental constraints:

$$\chi^2 = \sum_i^N \frac{(C_i - P_i)^2}{\sigma(C_i)^2 + \sigma(P_i)^2} + \sum_i^M \frac{(f_{\mathrm{SM}_i}^{\mathrm{obs}} - f_{\mathrm{SM}_i}^{\mathrm{fit}})^2}{\sigma(f_{\mathrm{SM}_i})^2}$$

N: number of observables studied

M: SM parameters: $\Delta\alpha_{\mathrm{had}}, m_t, M_Z$

C_i: experimentally measured value (constraint)

P_i: MSSM parameter-dependent prediction for the corresponding constraint

Assumption: measurements are uncorrelated - fulfilled to a high degree

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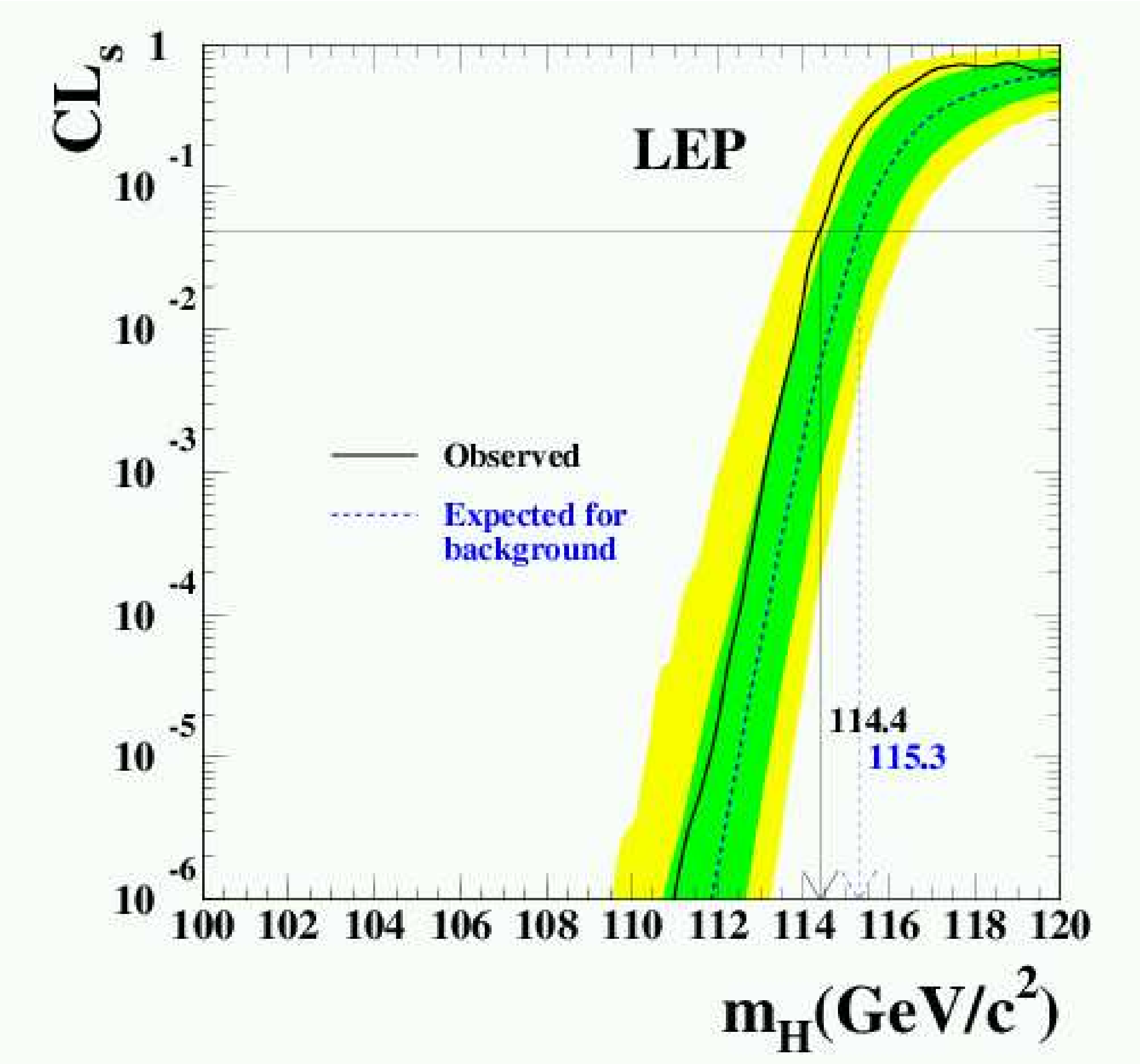
Treatment of M_h limits?

2. Pre-Higgs results

Pre-Higgs discovery in CMSSM:

SM bound of M_H search can be used [*LEP Higgs Working Group '03*]



CL_s can be used/transformed into χ^2 values

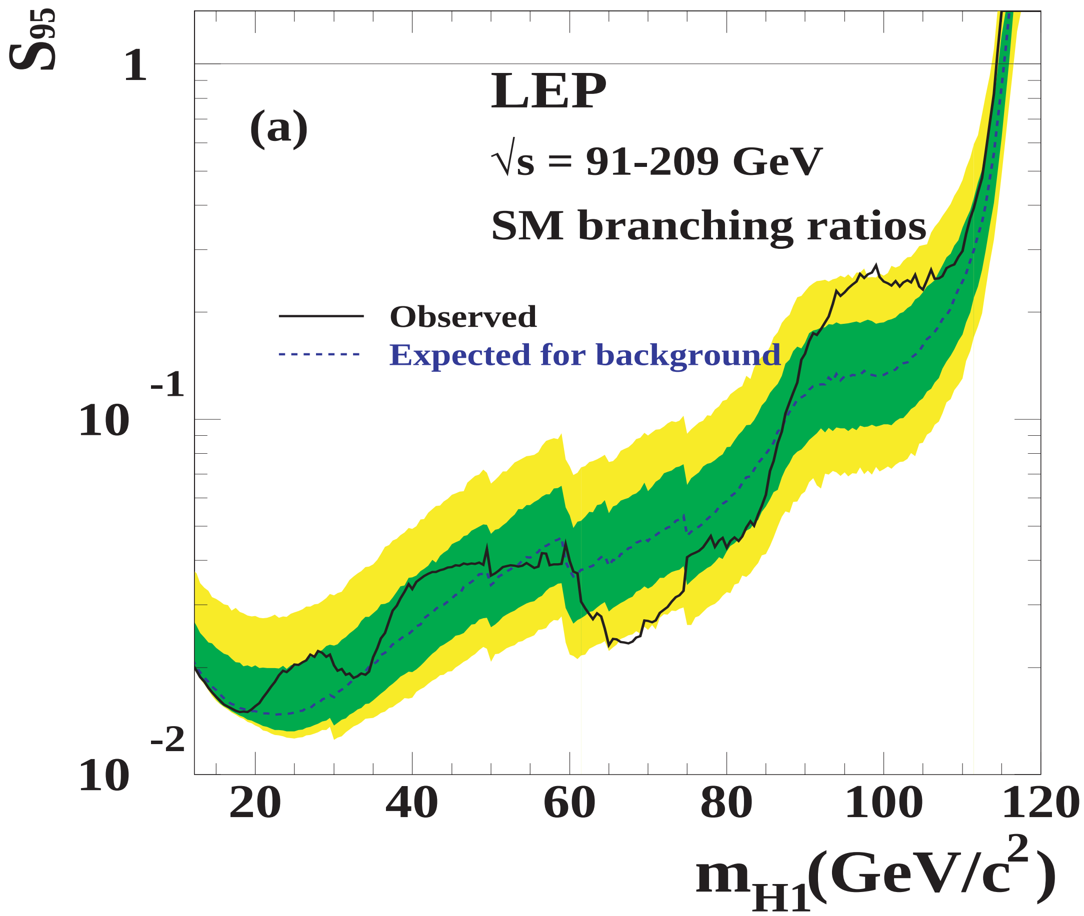
$\Rightarrow$ can be included into χ^2 evaluation

$\delta M_h^{\text{intr.}} \approx 3$ GeV

We use *FeynHiggs*

Pre-Higgs discovery in the NUHM1:

SM bound on M_H is reduced: $S_{95} \sim \sin^2(\beta - \alpha_{\rm eff})$



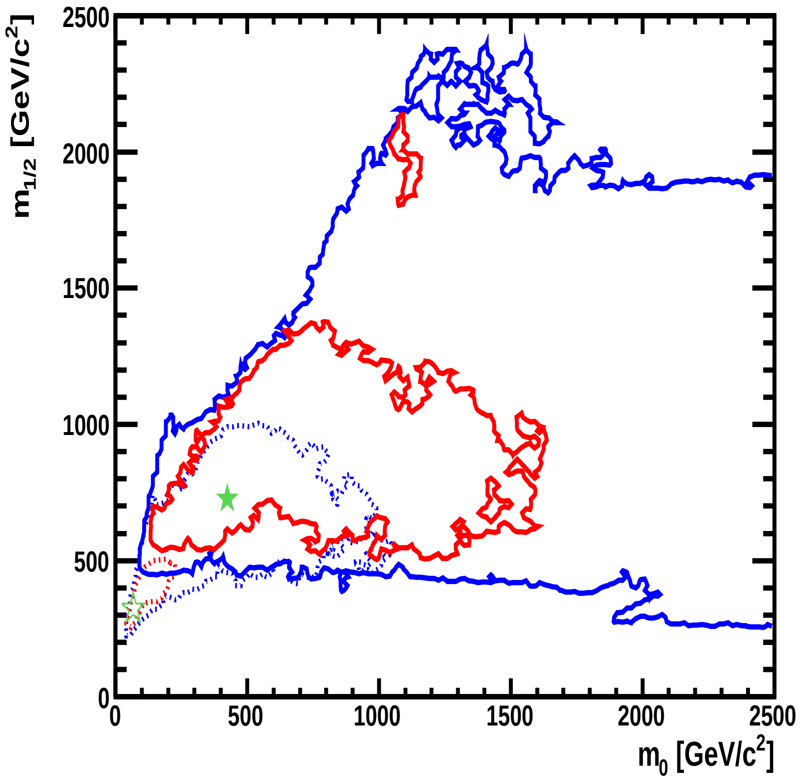
⇒ take into account the LEP SM Higgs bound . . .

. . . but shifted according to the reduced coupling

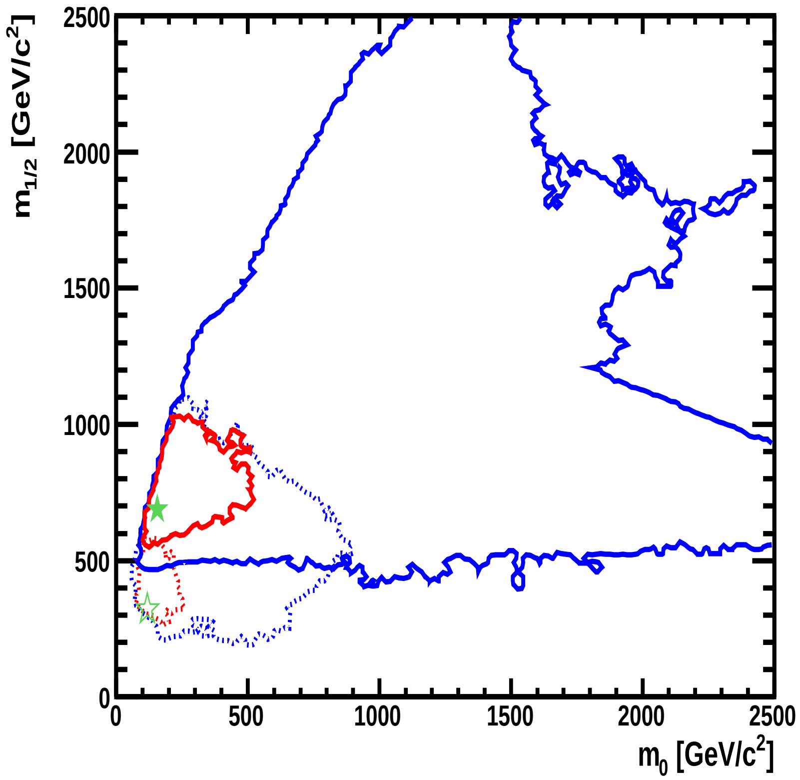
m_0-$m_{1/2}$ plane:

[2011]

CMSSM



NUHM1

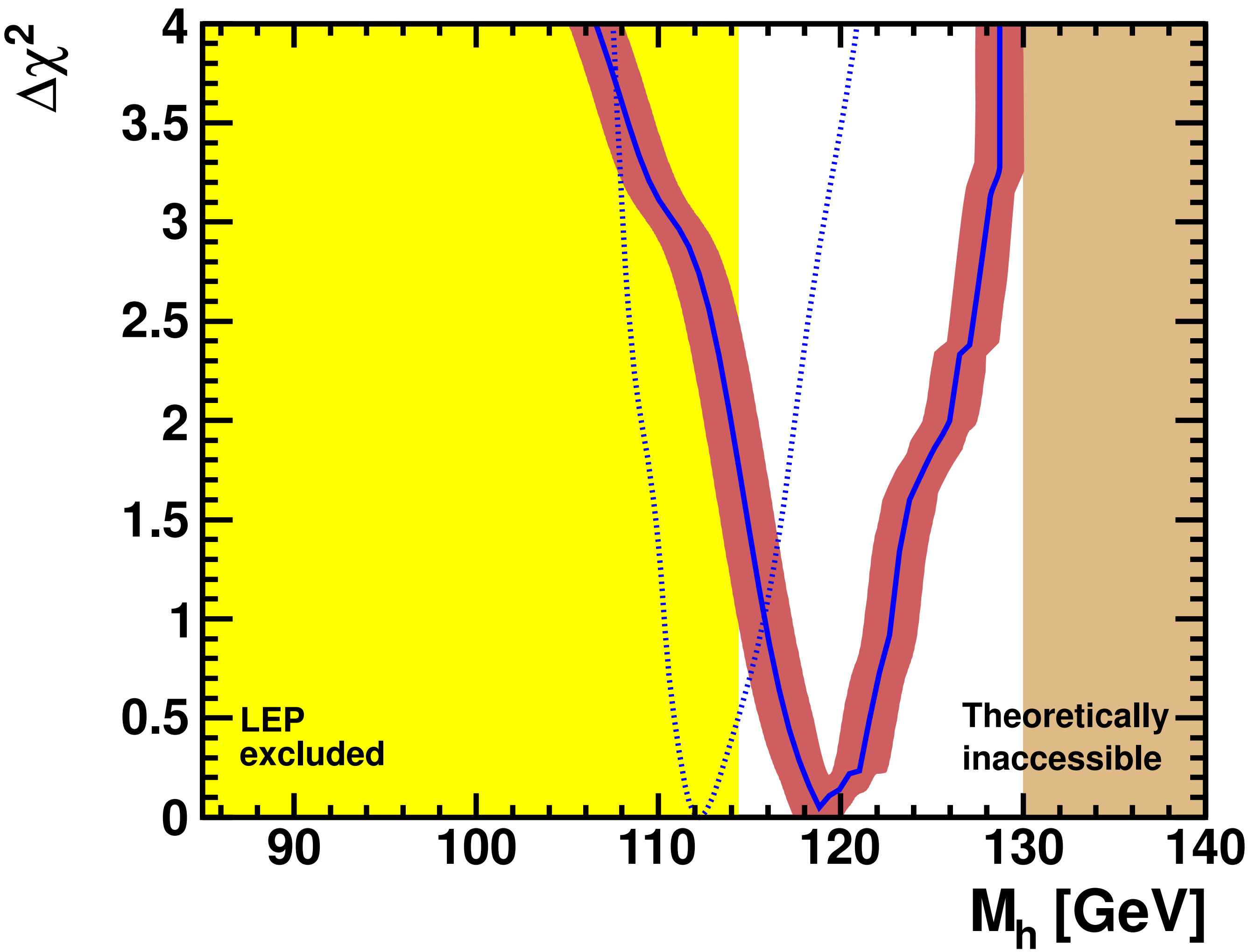


dotted: pre-LHC/Xenon, solid: post-LHC ($1\,\text{fb}^{-1}$)/Xenon

$\Rightarrow$ shift to higher masses

CMSSM: post-LHC (1 fb^{-1}) red band plot:

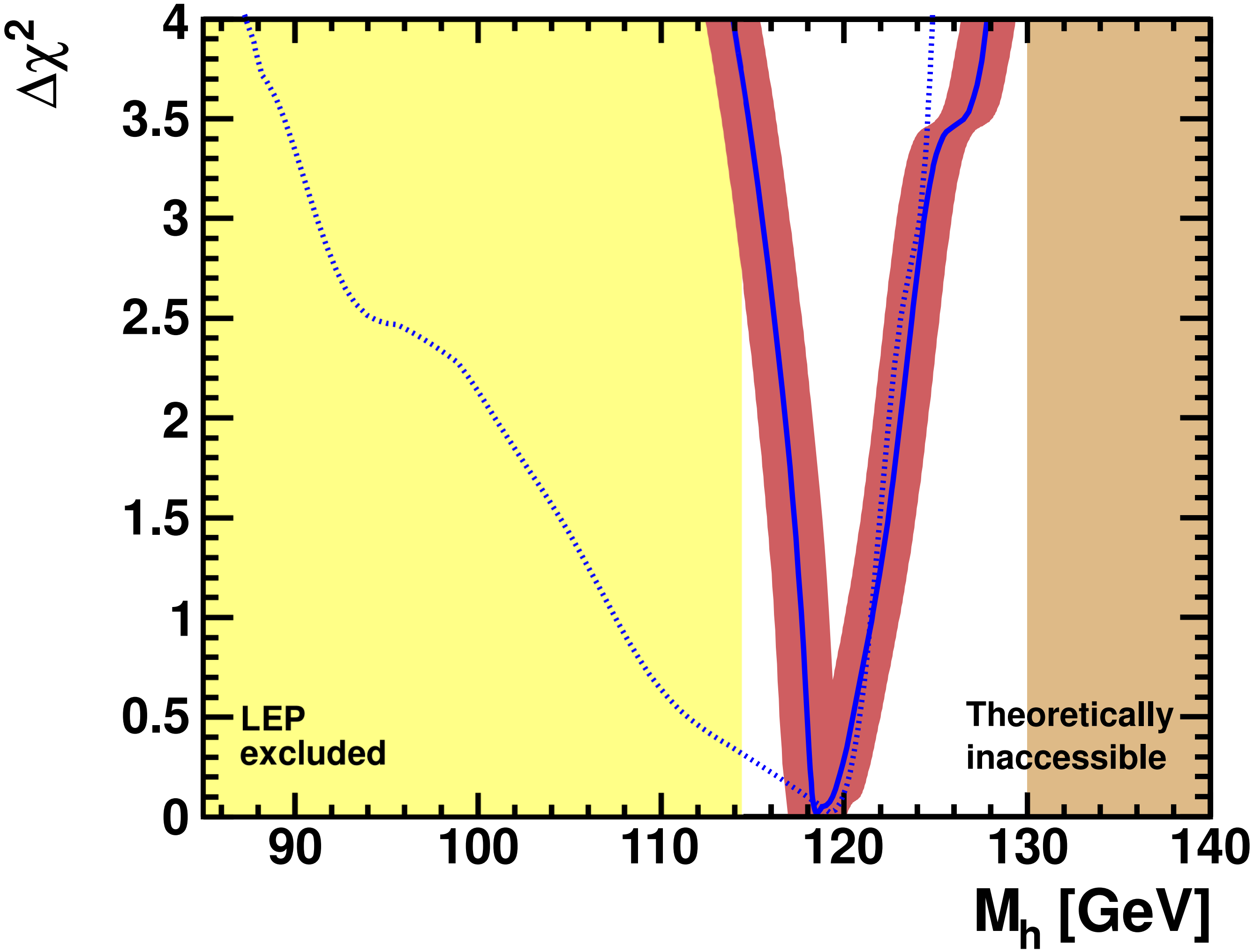
[2011]



$M_h = 119 \pm 3\,(\text{exp}) \pm 1.5(\text{theo})$ GeV $\Rightarrow$ fits "better" than pre-LHC

NUHM1: post-LHC (1 fb^{-1}) red band plot:

[2011]

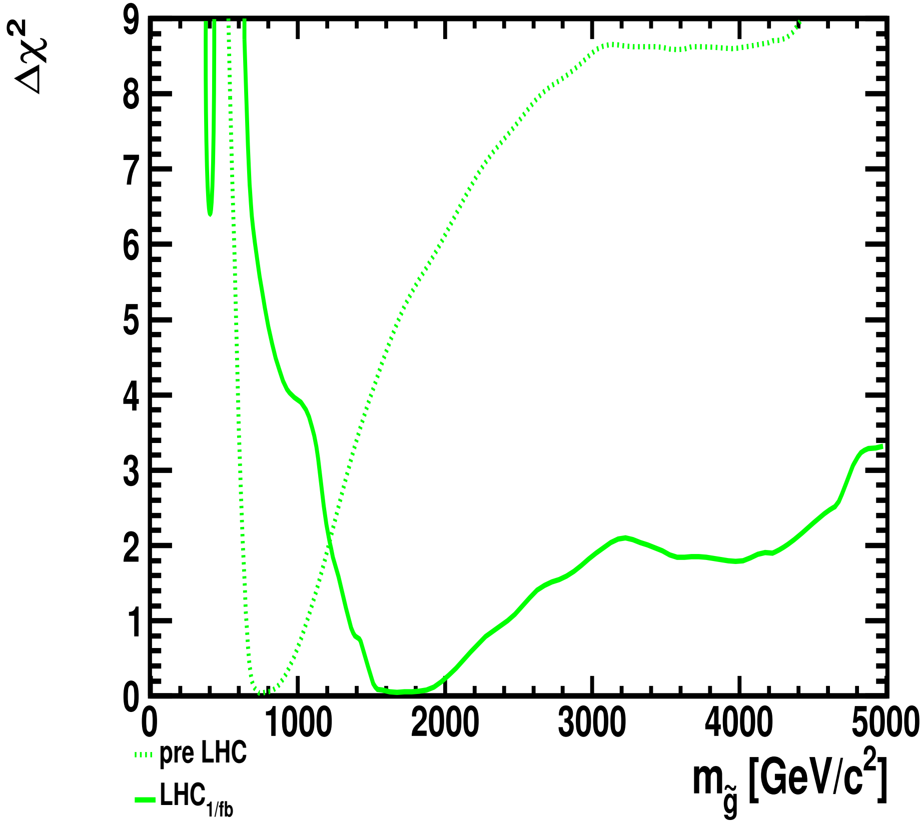


$M_h = 119^{+3}_{-1}\,(\text{exp}) \pm 1.5(\text{theo})$ GeV

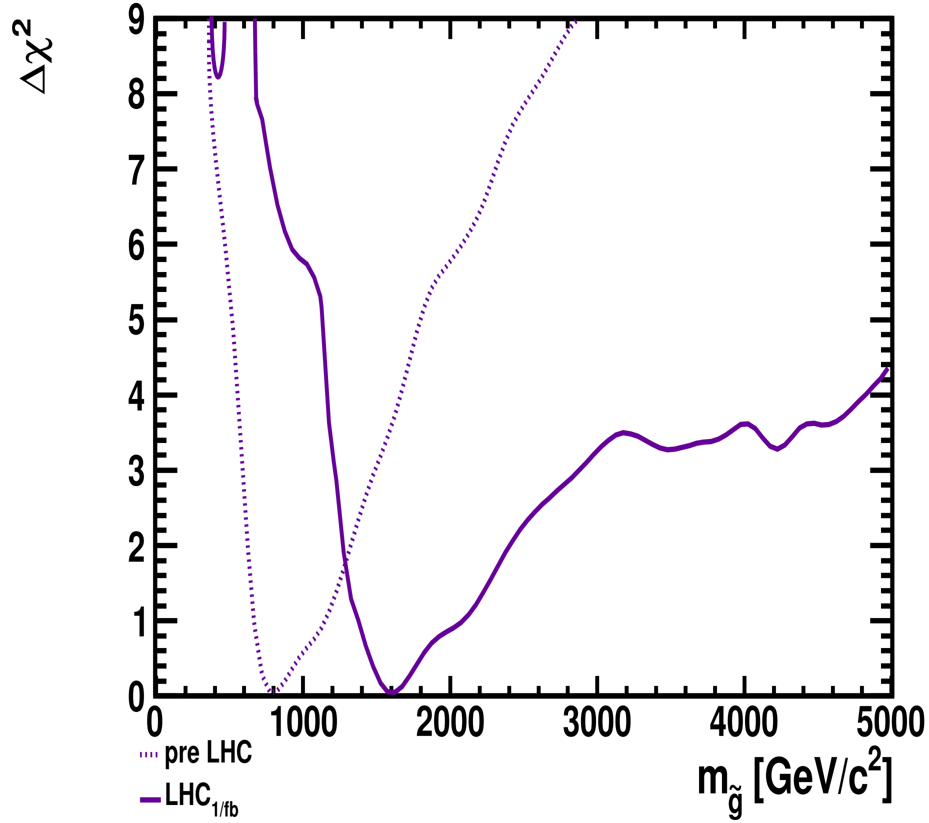
Starting point of the cascade: gluino

[2011]

CMSSM



NUHM1



dotted: pre-LHC/Xenon, solid: post-LHC (1 fb^{-1})/Xenon

⇒ substantial upward shift

What is happening to the χ^2?

Low energy data (mostly $(g-2)_\mu$) favors low SUSY mass scales

LHC data favors higher SUSY scales

$\Rightarrow$ tension, reflected in rising χ^2:

Model	Min. χ^2	Prob.	$m_{1/2}$ (GeV)	m_0 (GeV)	A_0 (GeV)	$\tan\beta$	$M_h^{\text{no LEP}}$ (GeV)
CMSSM	21.5/20	37%	360	90	-50	15	111
LHC 1 fb^{-1}	28.8/22	15%	780	450	-1100	41	119
NUHM1	20.8/18	29%	340	110	520	13	119
LHC 1 fb^{-1}	27.3/21	16%	730	150	-910	41	119

3. Post-Higgs results

⇒ Assume a Higgs measurement at pre-Higgs discovery best-fit point
But can be done for any M_h value!

experimental error: ± 1 GeV

theory error: ± 1.5 GeV

⇒ new contribution to

$$\chi^2 = \sum_i^N \frac{(C_i - P_i)^2}{\sigma(C_i)^2 + \sigma(P_i)^2} + \sum_i^M \frac{(f_{\mathrm{SM}_i}^{\mathrm{obs}} - f_{\mathrm{SM}_i}^{\mathrm{fit}})^2}{\sigma(f_{\mathrm{SM}_i})^2}$$

⇒ best-fit point is not moved

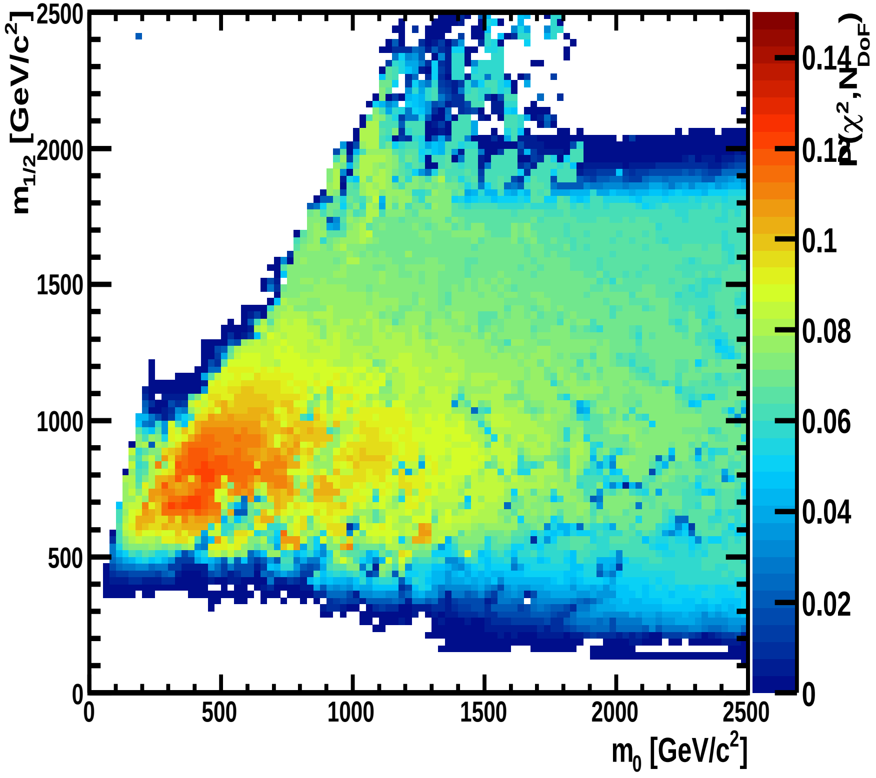
Pre-Higgs beset-fit point beyond LEP limit?

⇒ new Higgs constraint adds one d.o.f

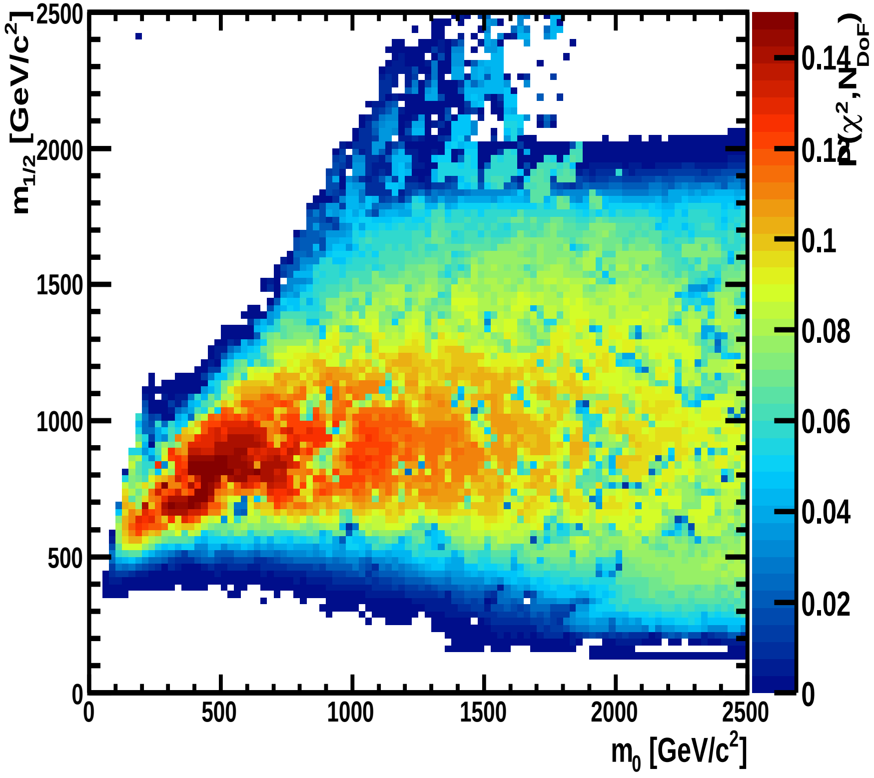
p value in m_0–$m_{1/2}$ plane (CMSSM): [*PRELIMINARY*]

[*2011*]

pre-Higgs



post-Higgs



⇒ similar preferred regions, $m_{1/2}$ ranges partially reduced

⇒ higher p value!

p value in m_0–$m_{1/2}$ plane (NUHM1): [*PRELIMINARY*]

[*2011*]

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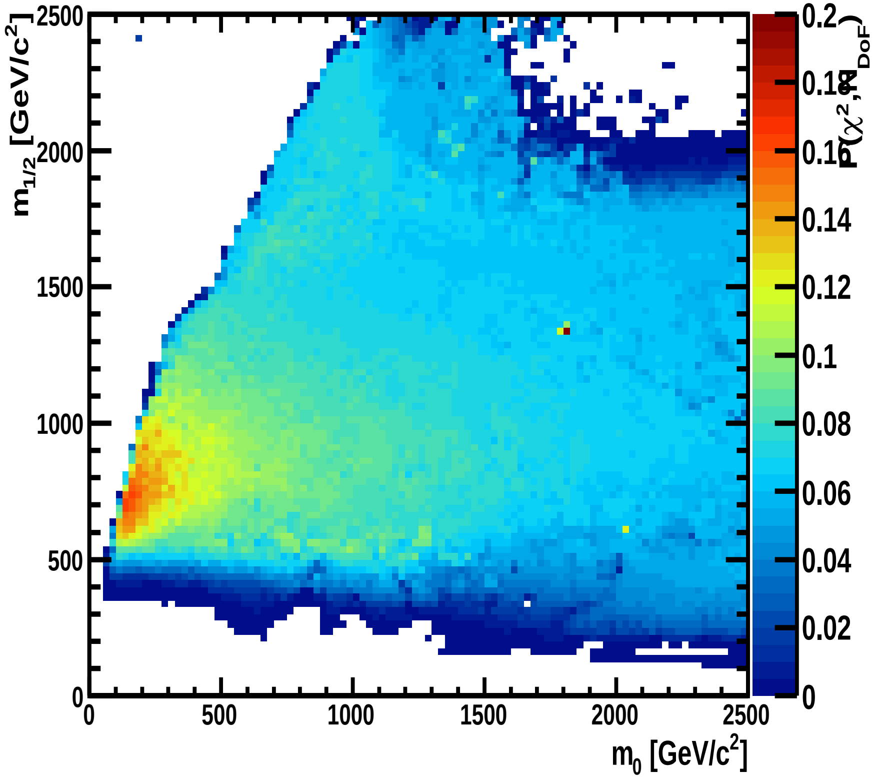

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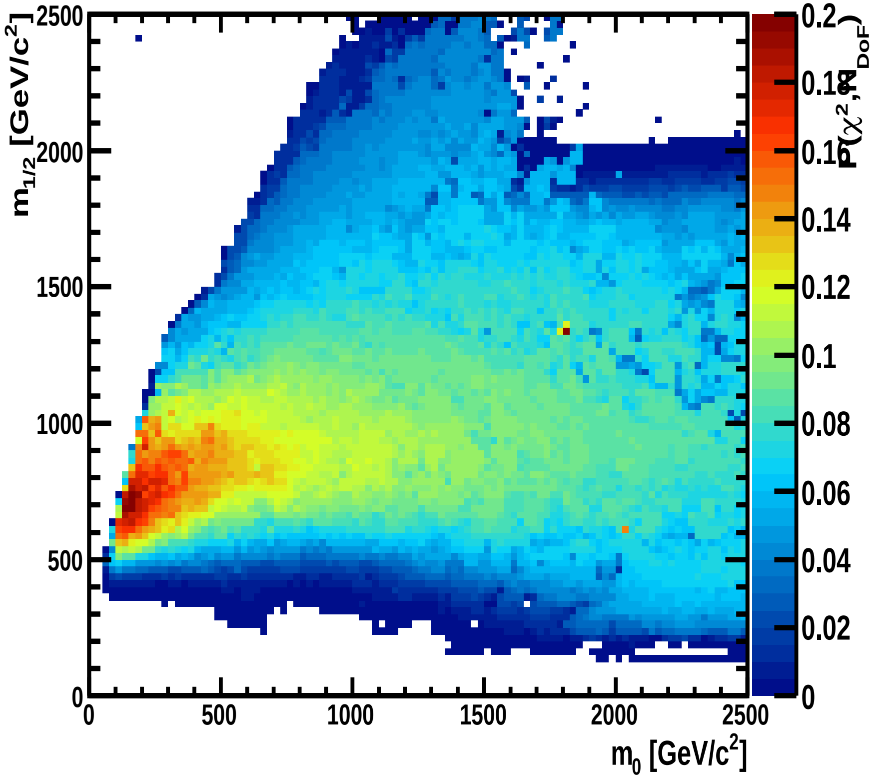

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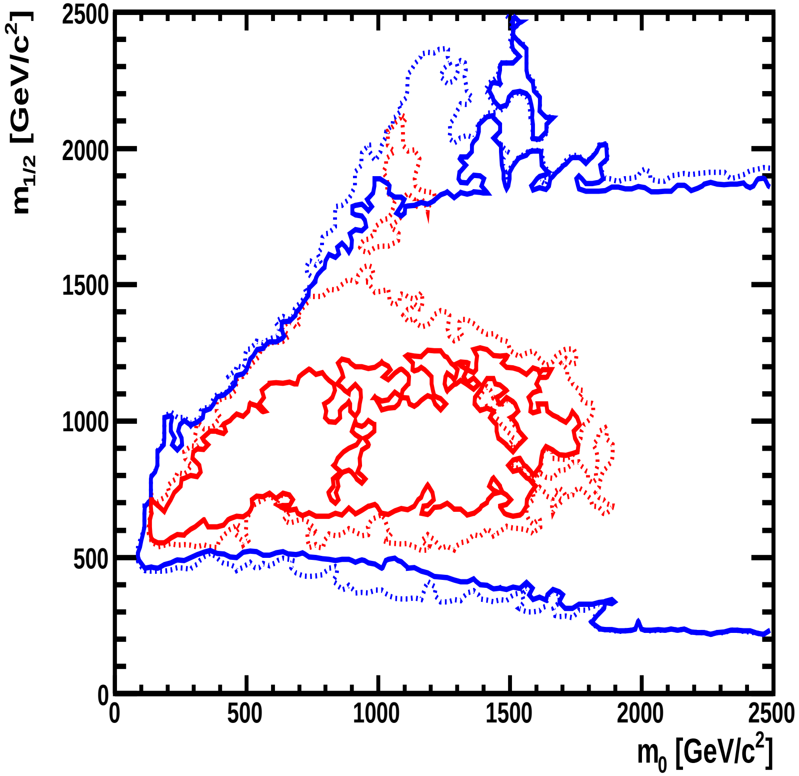
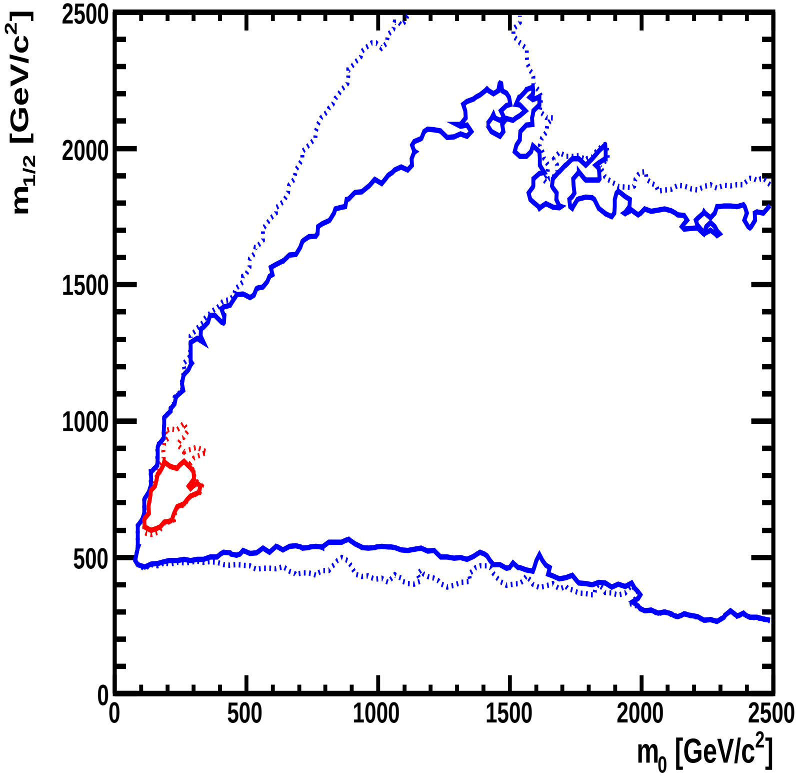
Preferred regions in m_0–$m_{1/2}$ plane: [*PRELIMINARY*]

[*2011*]

CMSSM NUHM1





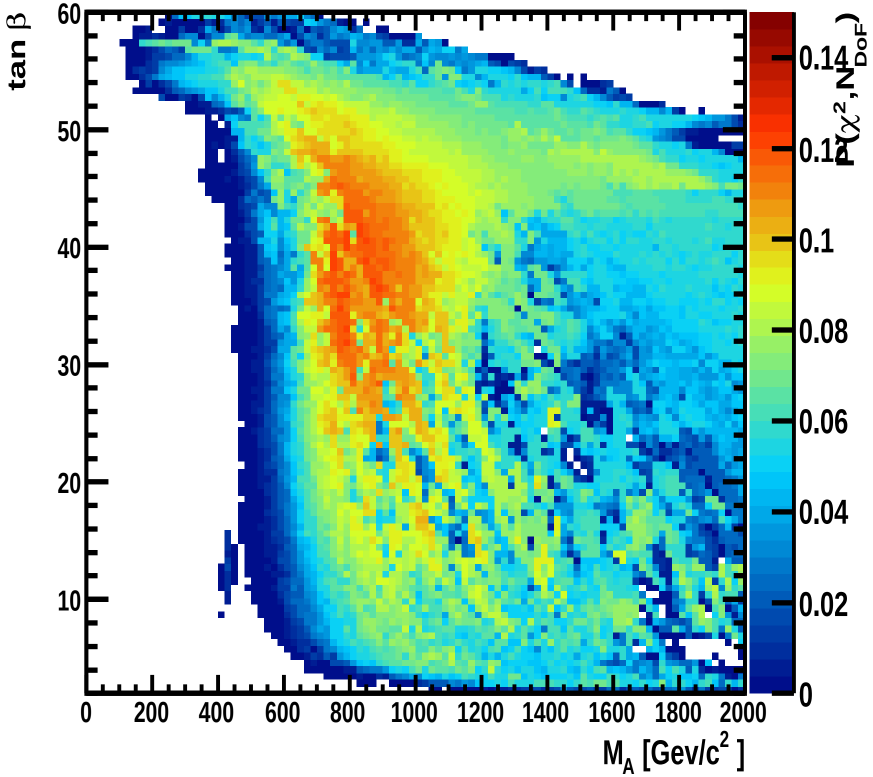
$\Rightarrow m_{1/2}$ ranges partially reduced

$\Rightarrow m_0$ hardly affected

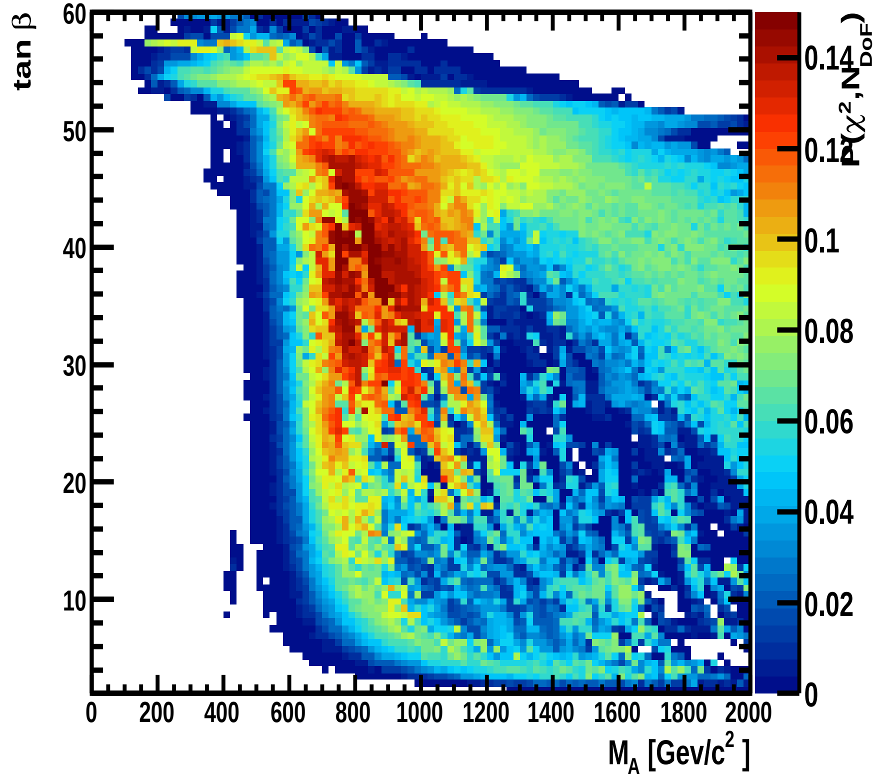
p value in M_A–tan β plane (CMSSM): [*PRELIMINARY*]

[*2011*]

pre-Higgs



post-Higgs



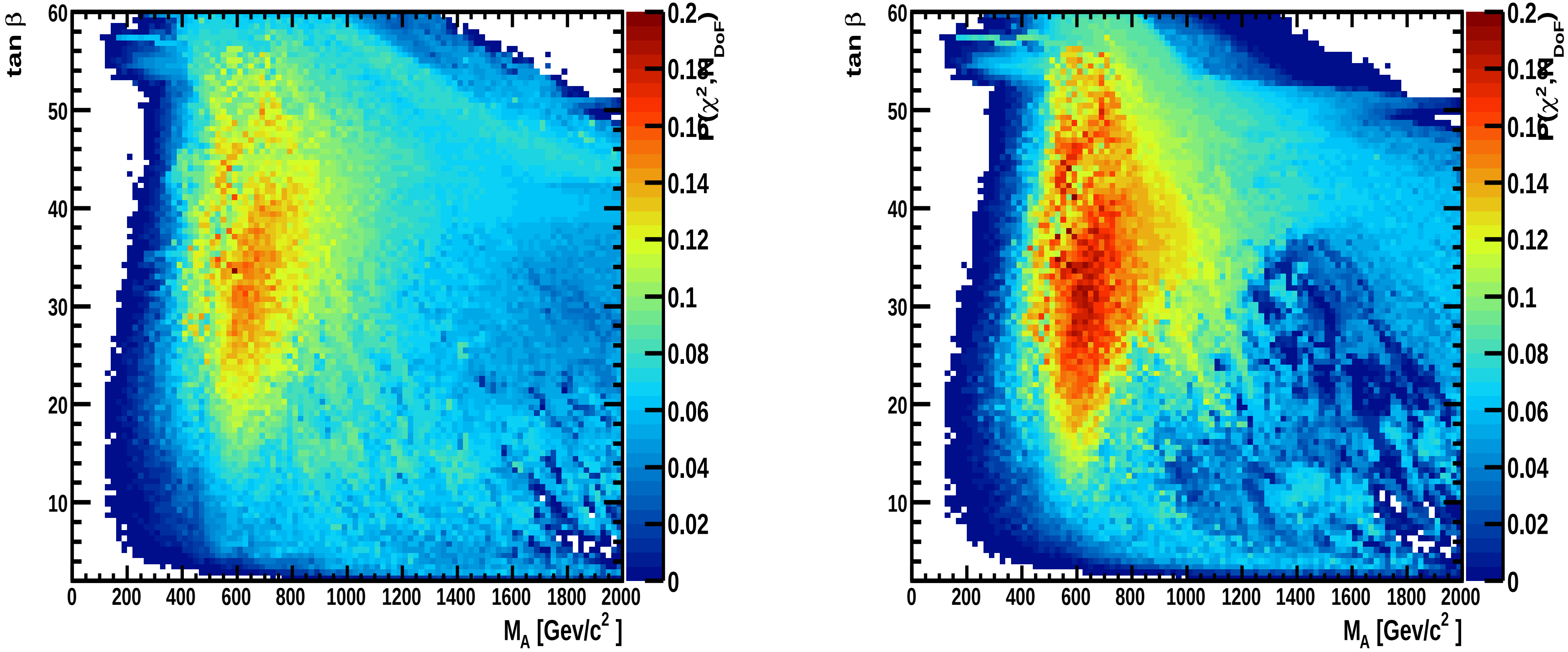
$\Rightarrow$ similar preferred regions, tan β ranges partially reduced

$\Rightarrow$ higher p value!

p value in M_A–tan β plane (NUHM1): [*PRELIMINARY*]

[*2011*]

pre-Higgs post-Higgs



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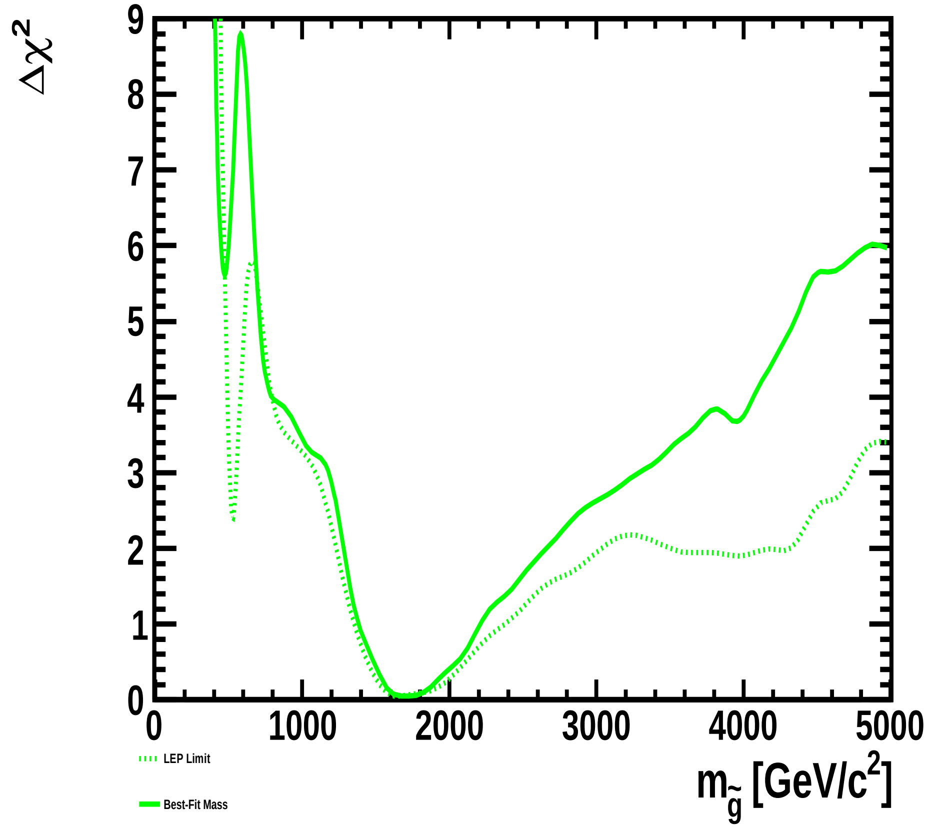
$\Delta\chi^2$ for $m_{\tilde{g}}$:

[PRELIMINARY]

[2011]

CMSSM



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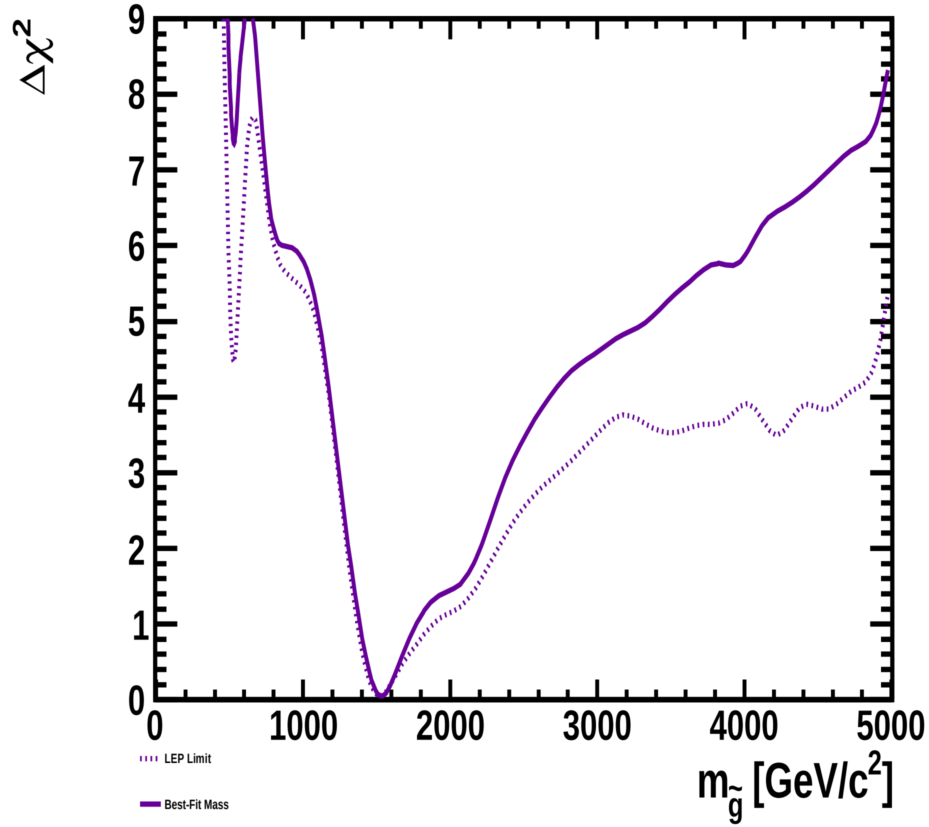

$\Rightarrow$ same preferred values

$\Rightarrow$ higher $\Delta\chi^2$ at higher $m_{\tilde{g}}$ values

Future plans:

- include other M_h values
- include “real” LHC results
- investigate other models
- . . .