Expectation for direct detection

An interplay between
Accelerator Physics and Particle Astrophysics

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IPP, ETH Zurich

TeVPA 2010 conference, Paris – July 22 2010

Evaluating the expectation

ETH Institute for Particle Physics

- Constraints on Supersymmetry already exist:
  - **Low energy (precision) data**
    - Flavour Physics (in particular B Physics), g-2
  - **High energy (precision) data**
    - Precision electroweak observables (e.g., m_{top}, M_W)
  - **Cosmology/astrophysical data**
    - in particular: relic density $\Omega h^2 = 0.1099 \pm 0.0062$ (exp)

      arXiv:0803.0586 [astro-ph]
  - **Exploit it to set "expectation"**
    - within a SUSY model

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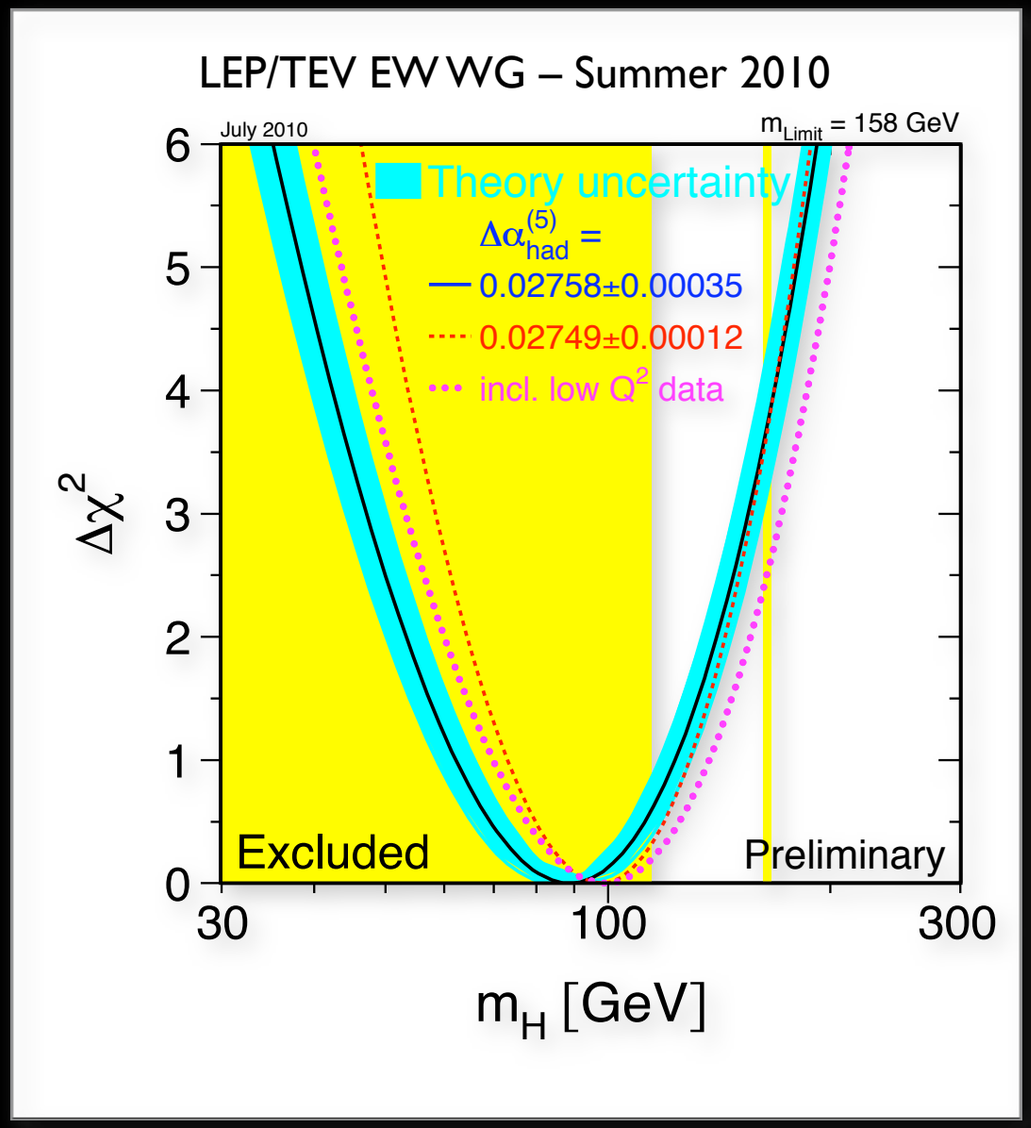

A famous example of expectation: Standard Model Higgs mass prediction from LEP/TeV EW precision observables

Global fits

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- How to exploit this information?
  - **a consistent set of experimental measurements**
    - including astrophysical measurements
  - **state-of-the-art theoretical predictions ("tools")**
    - including astrophysical predictions...
  - **a "framework" to consistently combine predictions and measurements**

- The MasterCode collaboration
  - **a collaboration between theory and experiment**
    - from High-energy and flavour Physics, and Cosmology
  - **an effort to combine and interpret today's constraints**
    - other efforts exist (see R. Trotta's talk this morning)

O. Buchmüller, R. Cavanaugh,
A. De Roeck, J. Ellis, H. Flächer,
S. Heinemeyer, G. Isidori, K. Olive,
S. Rogerson, F. Ronga, G. Weiglein

The "framework"

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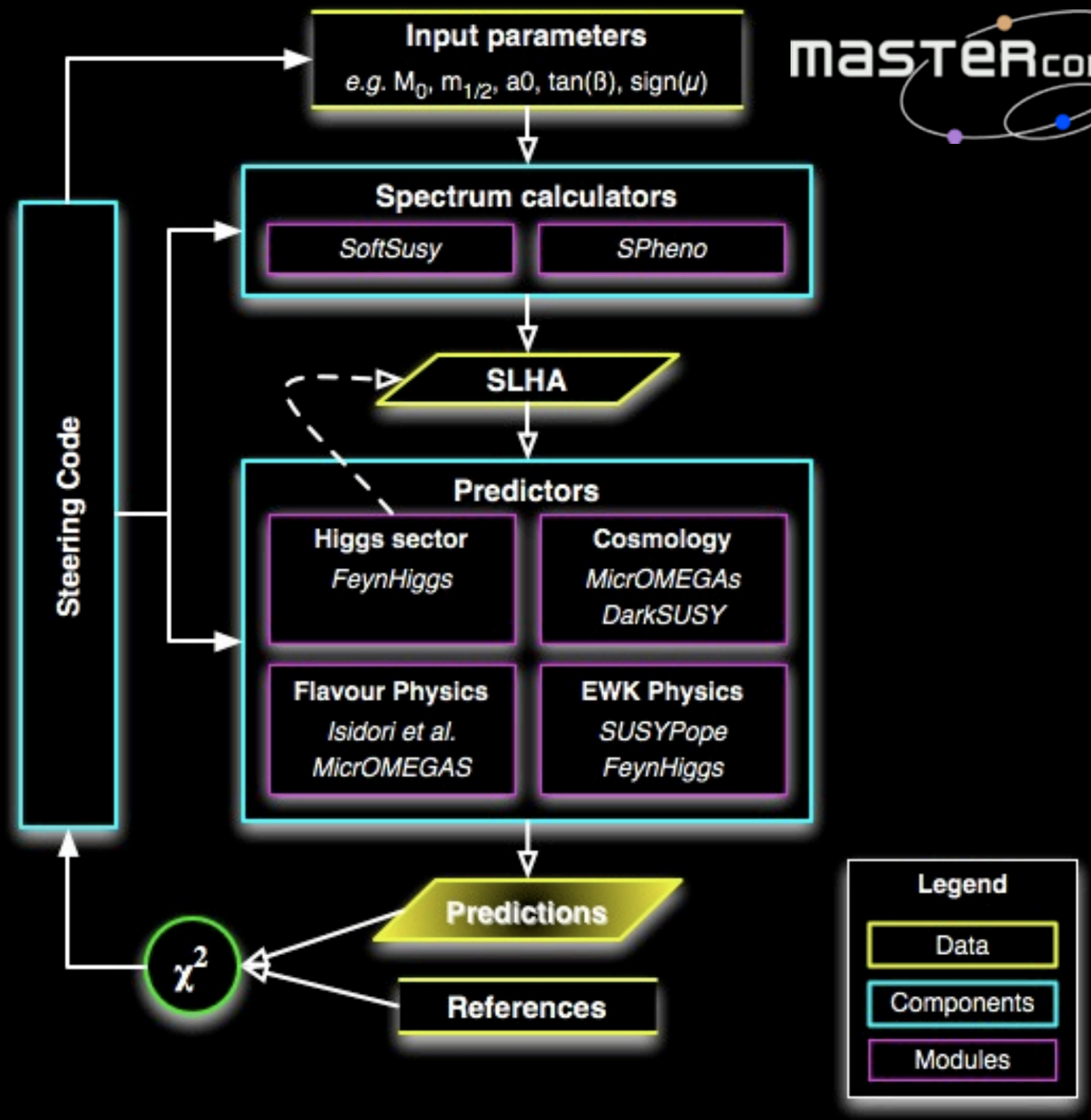
- Consistency
  - **SLHA interface**
- Modularity
  - **Compare calculations**
  - **Add/remove predictions**
- State-of-the-art "tools"
  - **Directly from experts**
- Flexibility
  - **`Minuit` fit**
  - **Markov Chain MC**
  - **input to external tool**



Building the χ^2

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

- *Multi-parameter χ^2 variable*
  - **C_i – experimental constraints**
  - ***P_i – predicted value for a given parameter set***
- *Fitting for all model parameters*
  - ***CMSSM: M_0, $M_{1/2}$, A_0, tanβ (sign(μ)=1)***
  - ***NUHM1: CMSSM parameters + one free Higgs mass parameter (e.g., M_A)***
- *including relevant SM uncertainties*
  - ***m_{top}, m_Z, Γ_Z, $\Delta\alpha_{had}$***

List of observables

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Low energy observables

$R(b \to s\gamma)$	SuFla*	micrOMEGAs
$R(B \to \tau\nu)$	SuFla	
$BR(K \to \tau\nu)$	SuFla	
$R(B \to X_s\ell\ell)$	SuFla	
$R(K \to \pi\nu\bar{\nu})$	SuFla	
$BR(B_s \to \ell\ell)$	SuFla	micrOMEGAs
$BR(B_d \to \ell\ell)$	SuFla	
$R(\Delta m_s)$	SuFla	
$R(\Delta m_s)/R(\Delta m_d)$	SuFla	
$R(\Delta m_K)$	SuFla	
$R(\Delta_0(K^*\gamma))$	SuperIso	
$\Delta(g-2)$	FeynHiggs	

Higgs sector observables

m_h^{light}	FeynHiggs	

Cosmology observables

Ωh^2	DarkSUSY	micrOMEGAs
σ_p^{SI}	DarkSUSY	micrOMEGAs

Electroweak observables

$\Delta\alpha^{(5)}_{\text{had}}(m_Z^2)$	FeynWZ
m_Z	FeynWZ
σ^0_{had}	FeynWZ
R_l	FeynWZ
$A_{\text{fb}}(\ell)$	FeynWZ
$A_\ell(P_\tau)$	FeynWZ
R_{b}	FeynWZ
R_{c}	FeynWZ
$A_{\text{fb}}(\text{b})$	FeynWZ
$A_{\text{fb}}(\text{c})$	FeynWZ
A_{b}	FeynWZ
A_{c}	FeynWZ
$A_\ell(\text{SLD})$	FeynWZ
$\sin^2\theta^\ell_{\text{w}}(Q_{\text{fb}})$	FeynWZ
m_{W}	FeynWZ
m_{t}	FeynWZ

* G. Isidori, P. Paradisi

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Compare calculations

Electroweak observables

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Fit methods & "data" samples

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- Fit methods
  - **Markov Chain Monte Carlo (MCMC)**
    - actually used as a mere *sampling* method (sampling density not used)
      - success and failure of the steps are defined by the χ^2
  - **χ^2 fit: `Minuit` minimisation**
    - used for "scans" or in conjunction with MCMCs to get the overall best minimum
- Data samples for MCMCs
  - **about 25 million points for each model (CMSSM & NUHM1)**

Probing the parameter space

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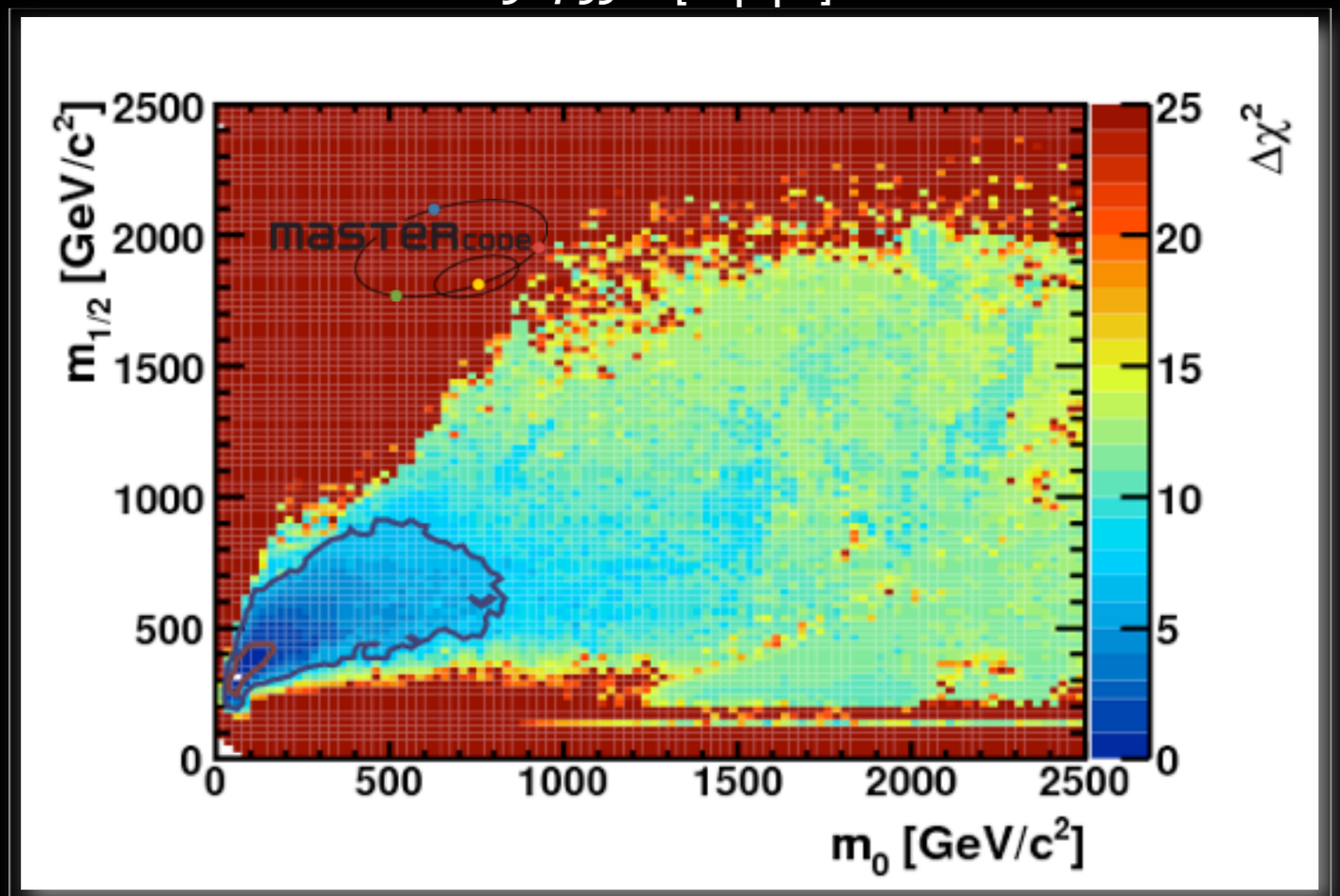
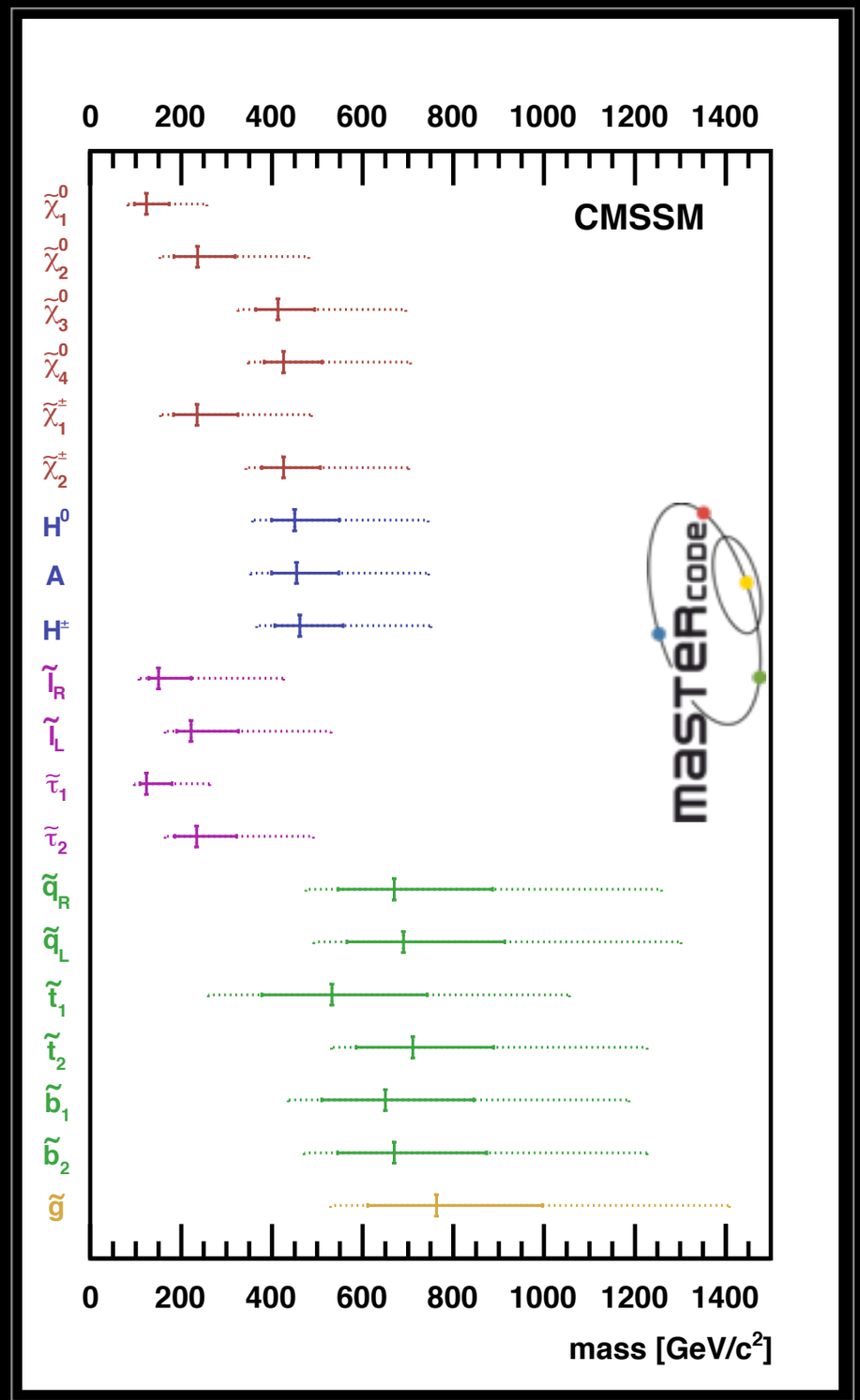
arXiv:0907.5568 [hep-ph]



CMSSM – Best fit point:

M_0=60 , $M_{1/2}$=310, A_0=130, tanβ=11



CMSSM spectrum at best fit point

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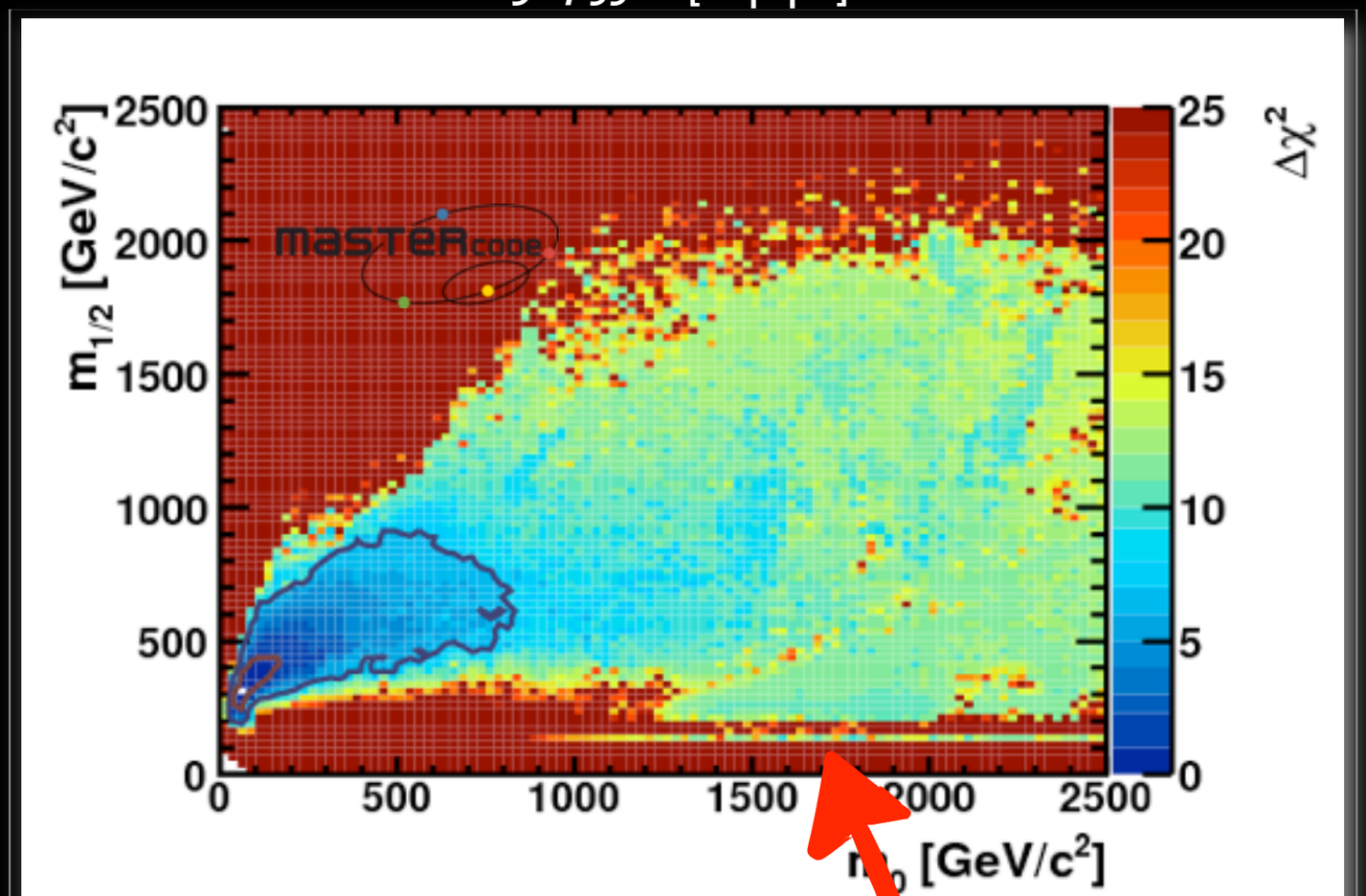

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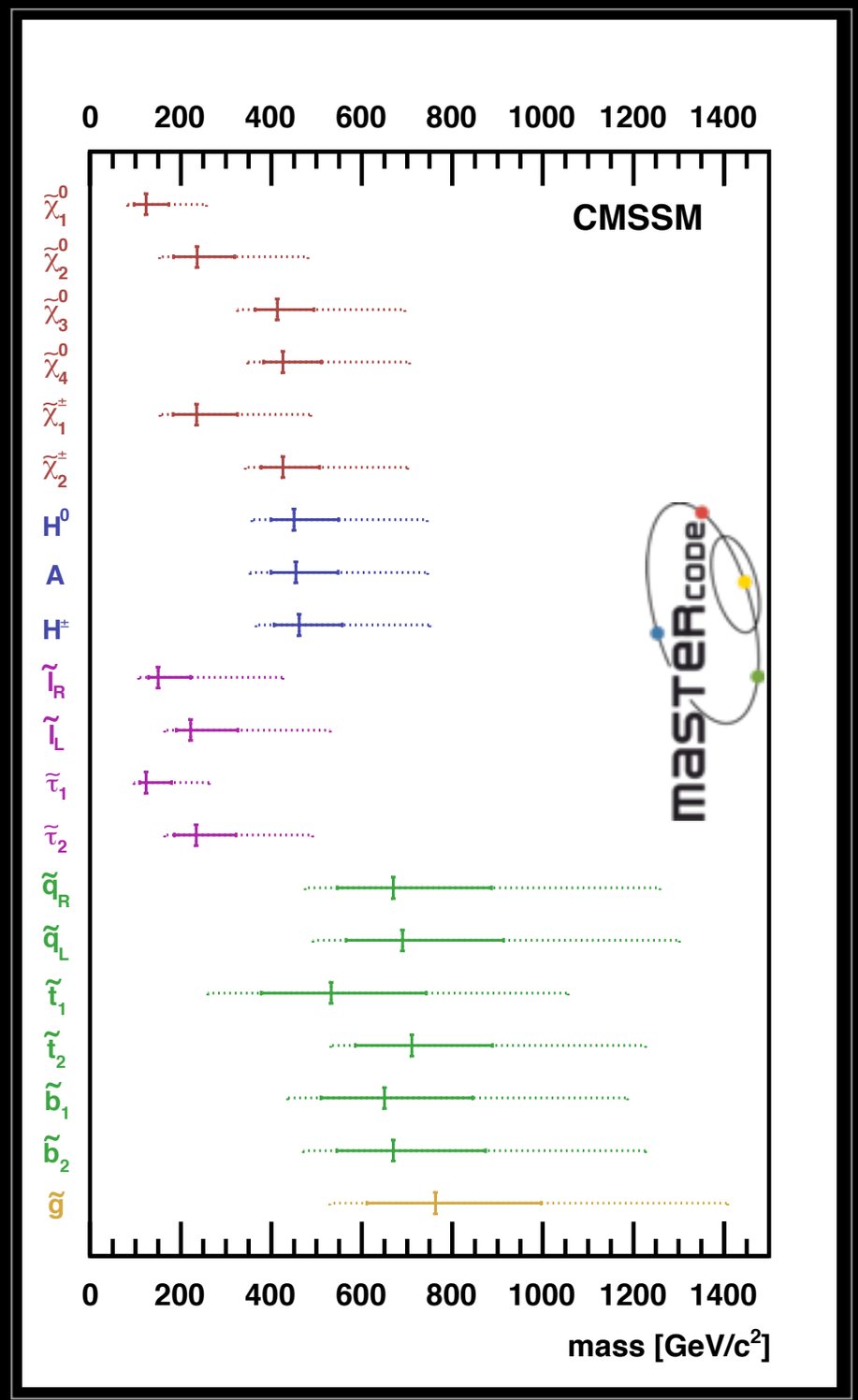
Higgs funnel!

$$2 \times m_{\tilde{\chi}^0} \lessapprox M_h$$



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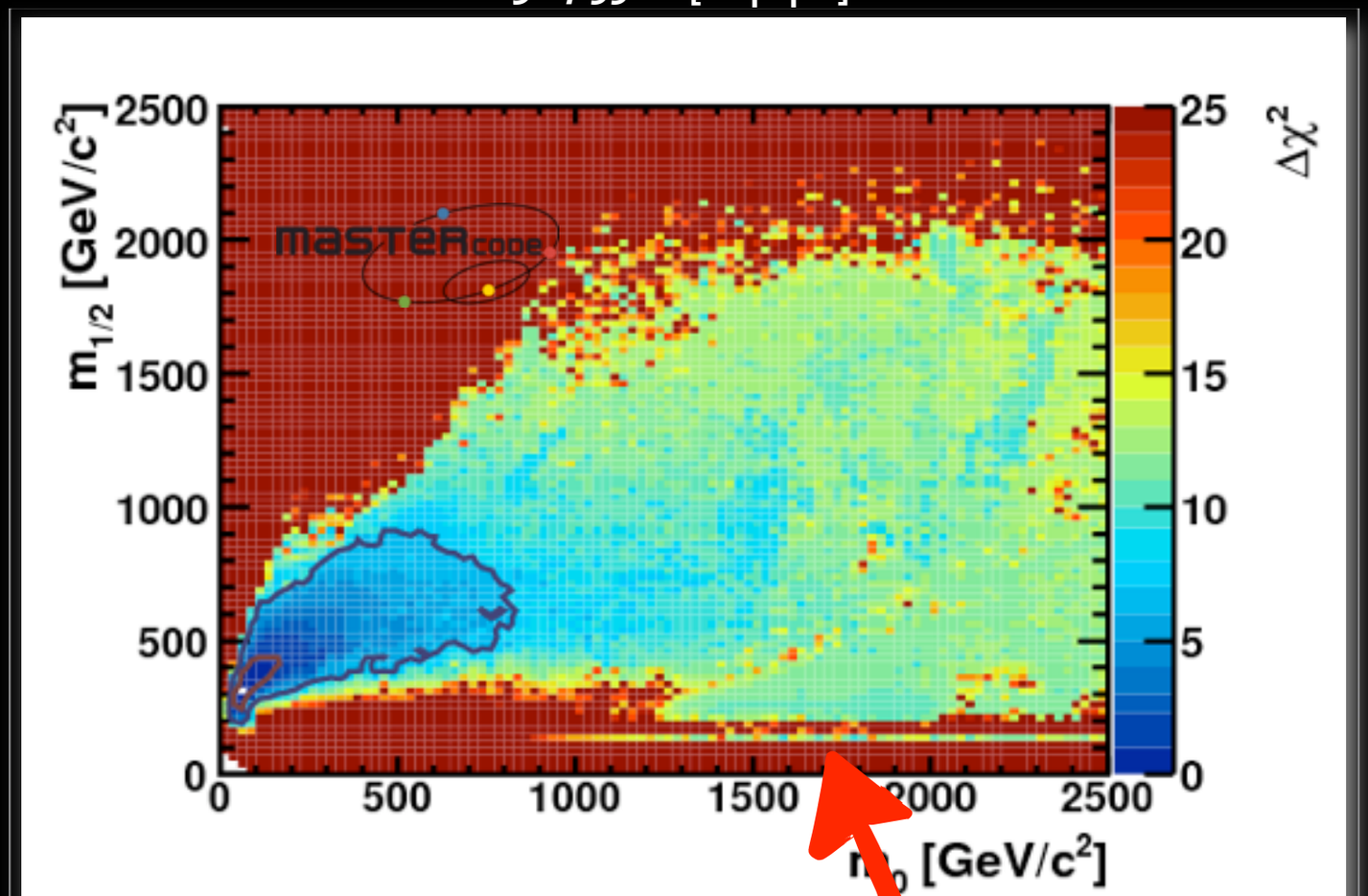

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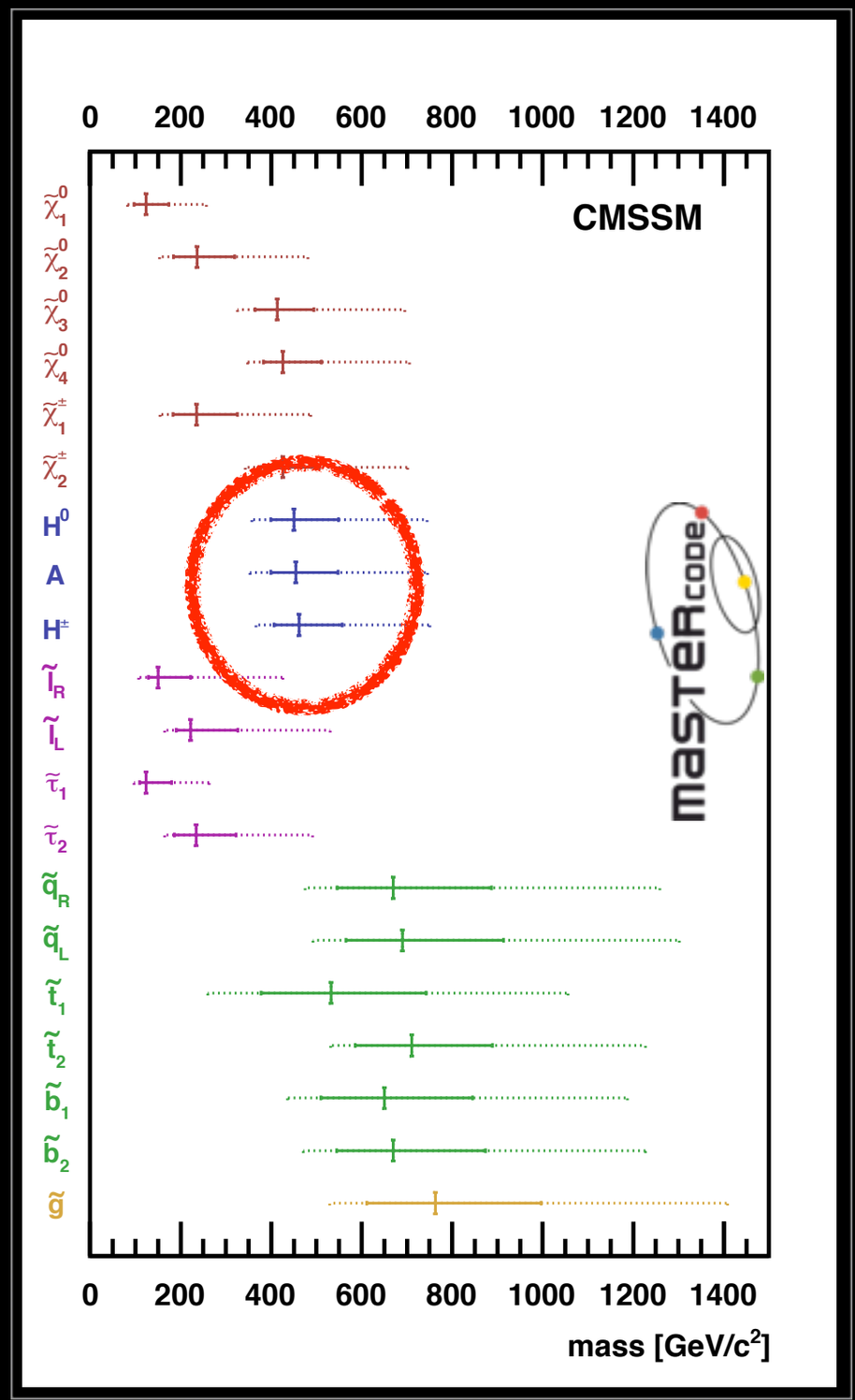

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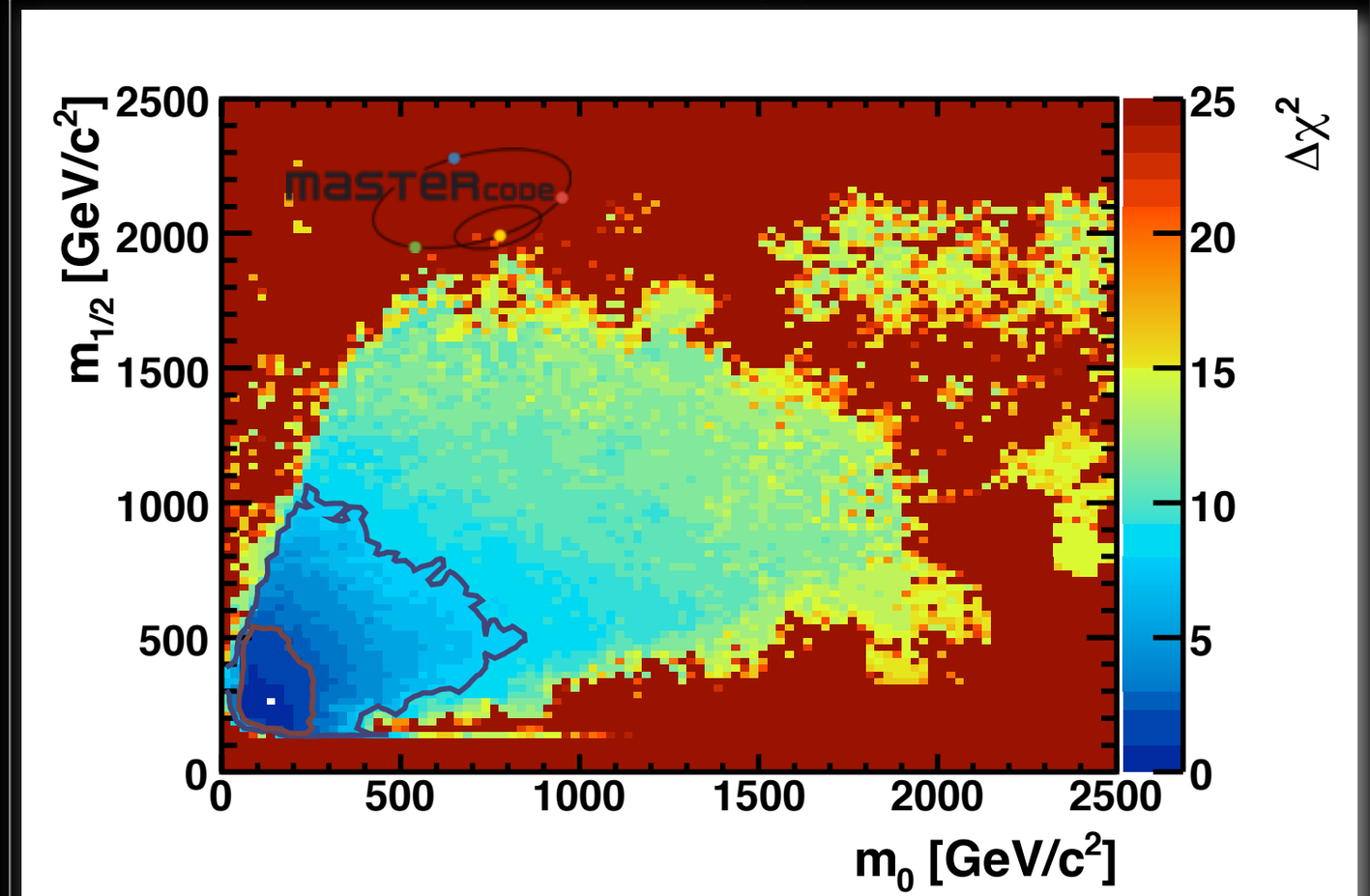
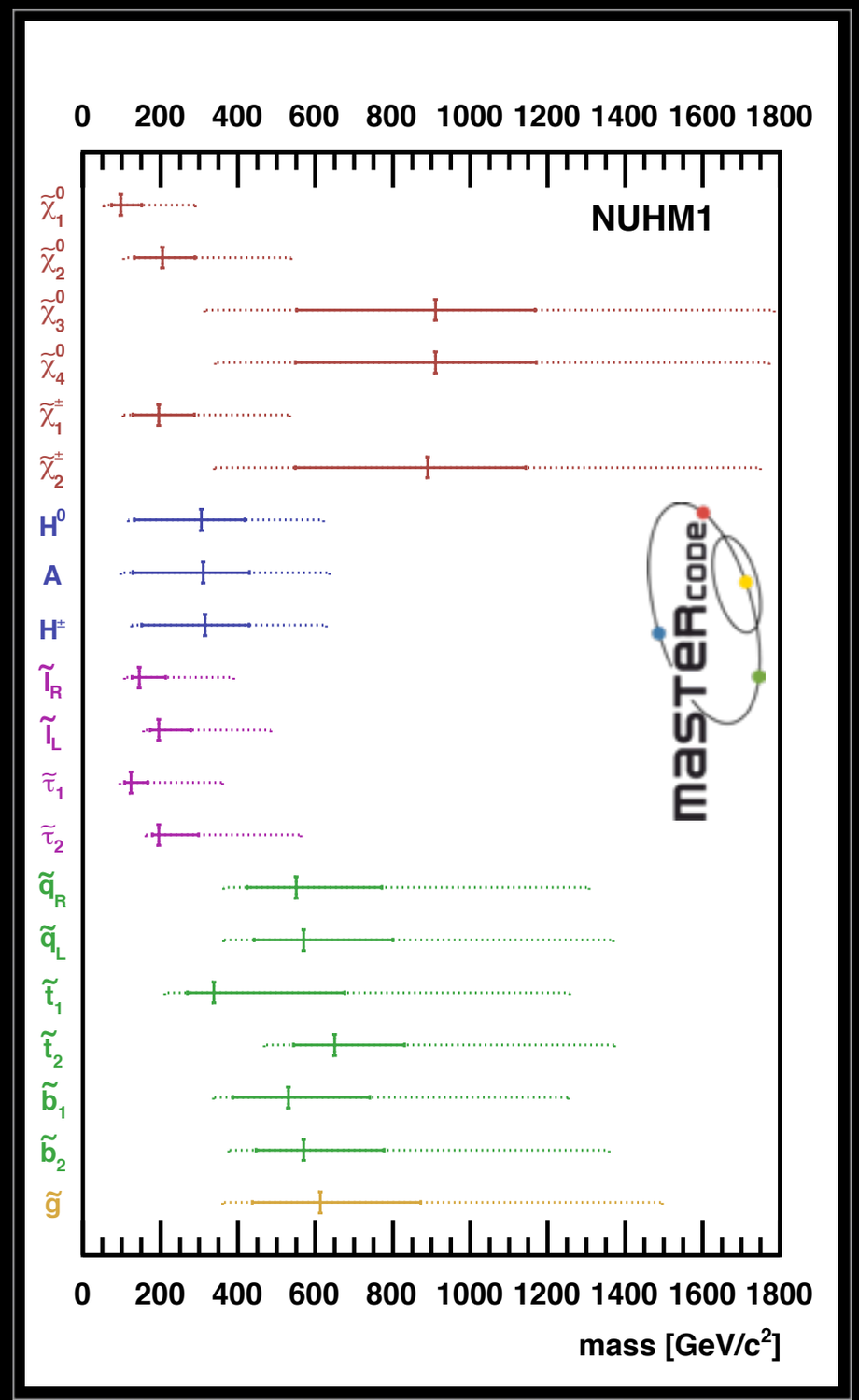


NUHM1 – Best fit point:

M_0=170 , $M_{1/2}$=260, A_0=-1330, tanβ=12



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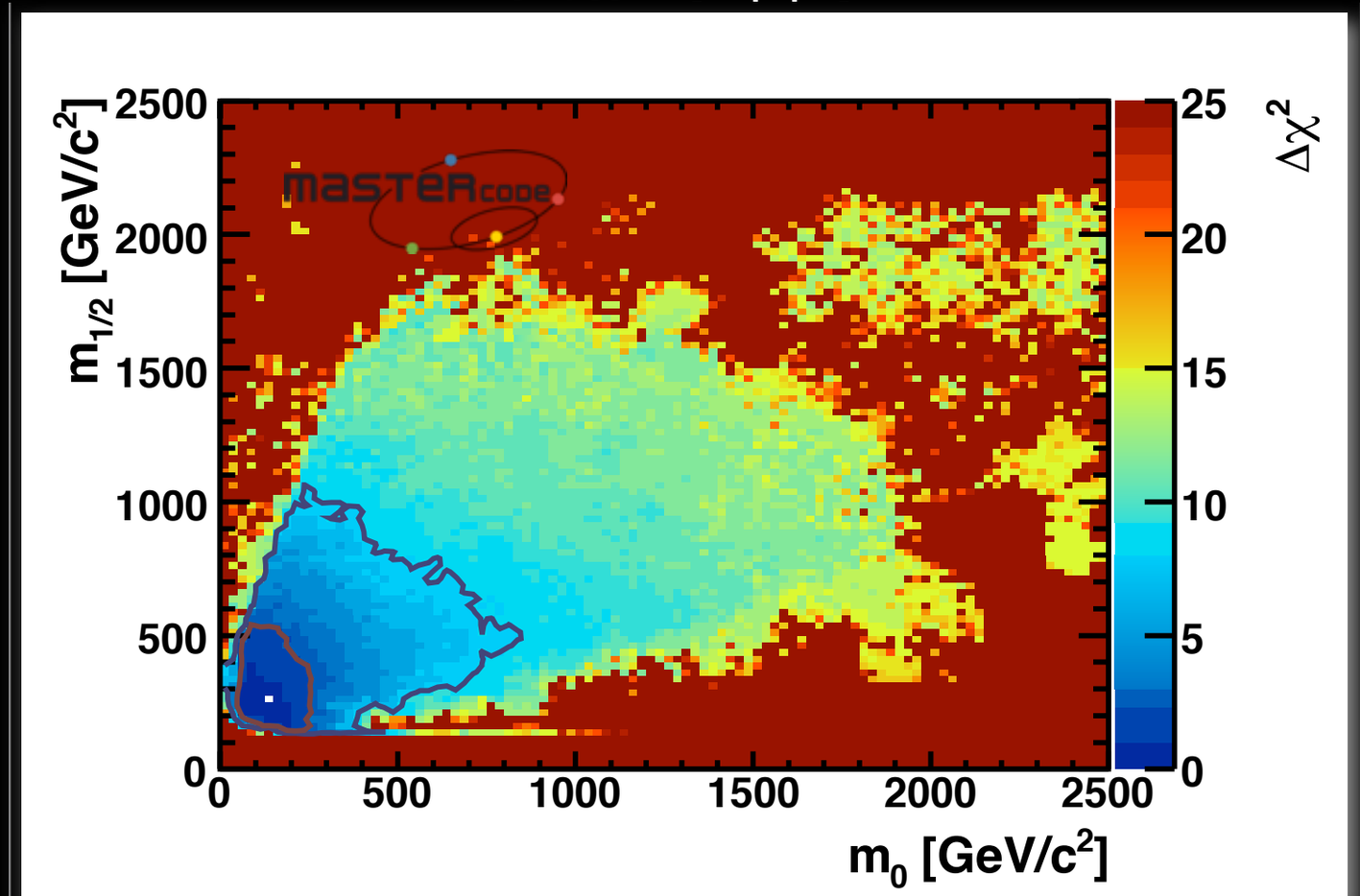
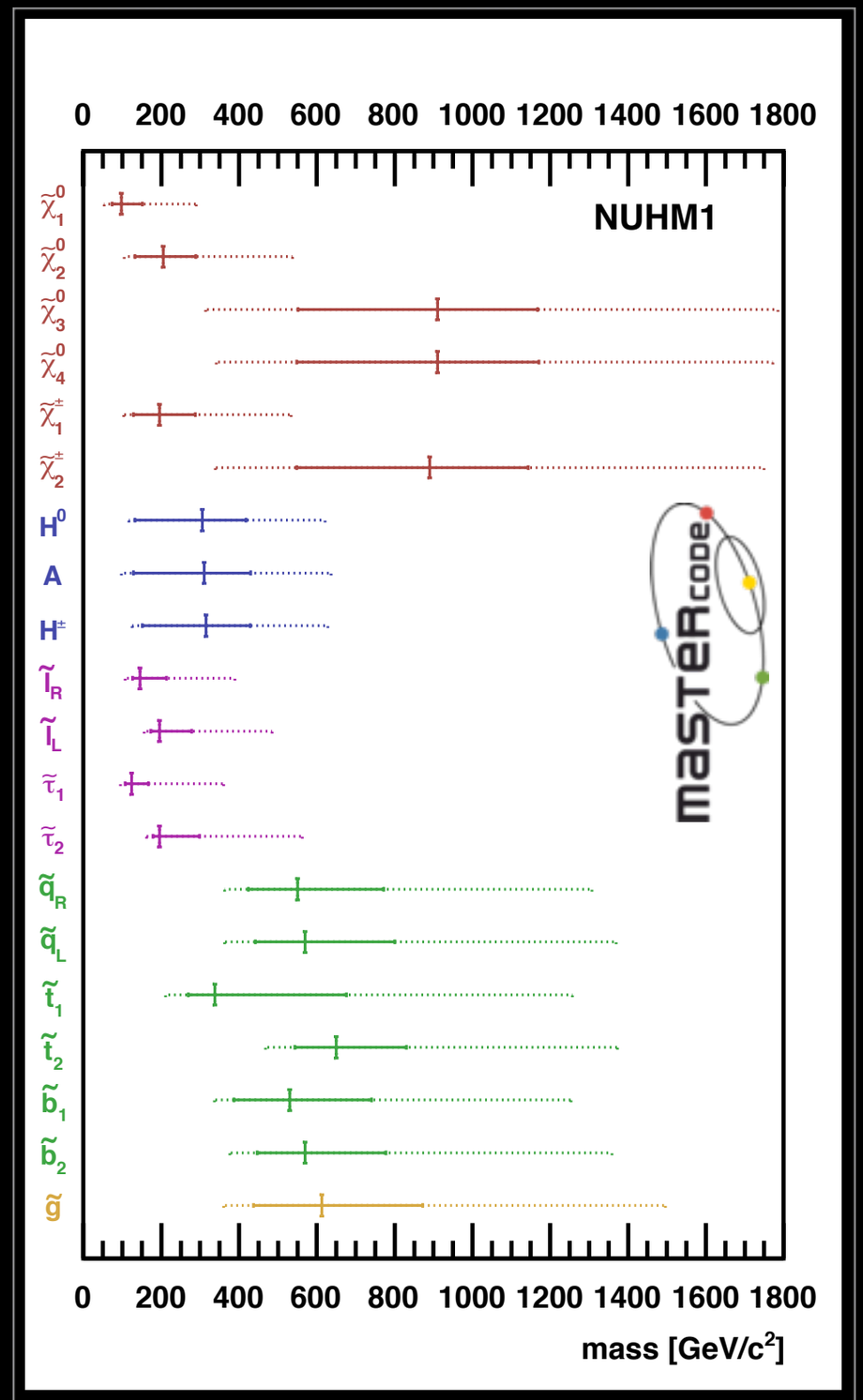


NUHM1 – Best fit point:
M_0=170 , $M_{1/2}$=260, A_0=-1330, tanβ=12

➠ Present data favours low mass SUSY



NUHM1 spectrum at best fit point

The key players (CMSSM)

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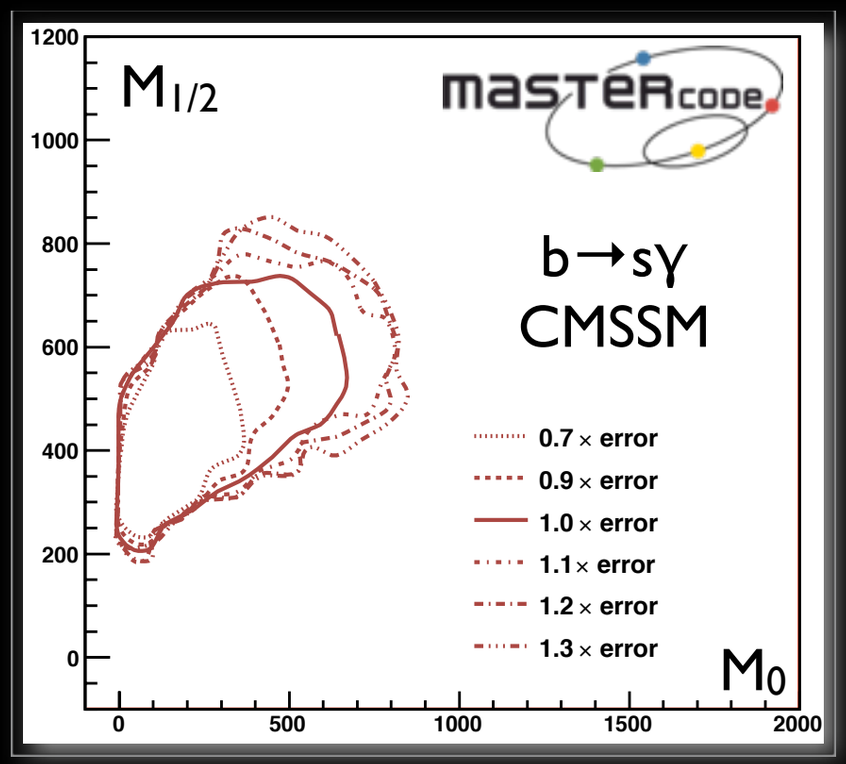
- Percent change of 95% C.L. contour area as a function of relative uncertainty

arXiv:0808.4128 [hep-ph]



The key players (CMSSM)

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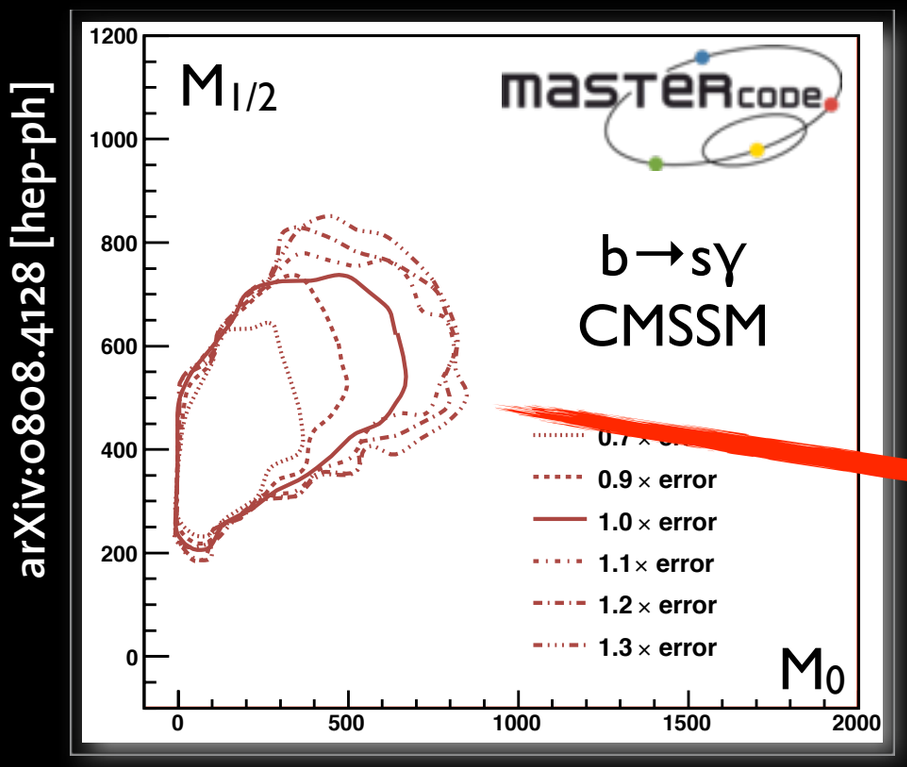
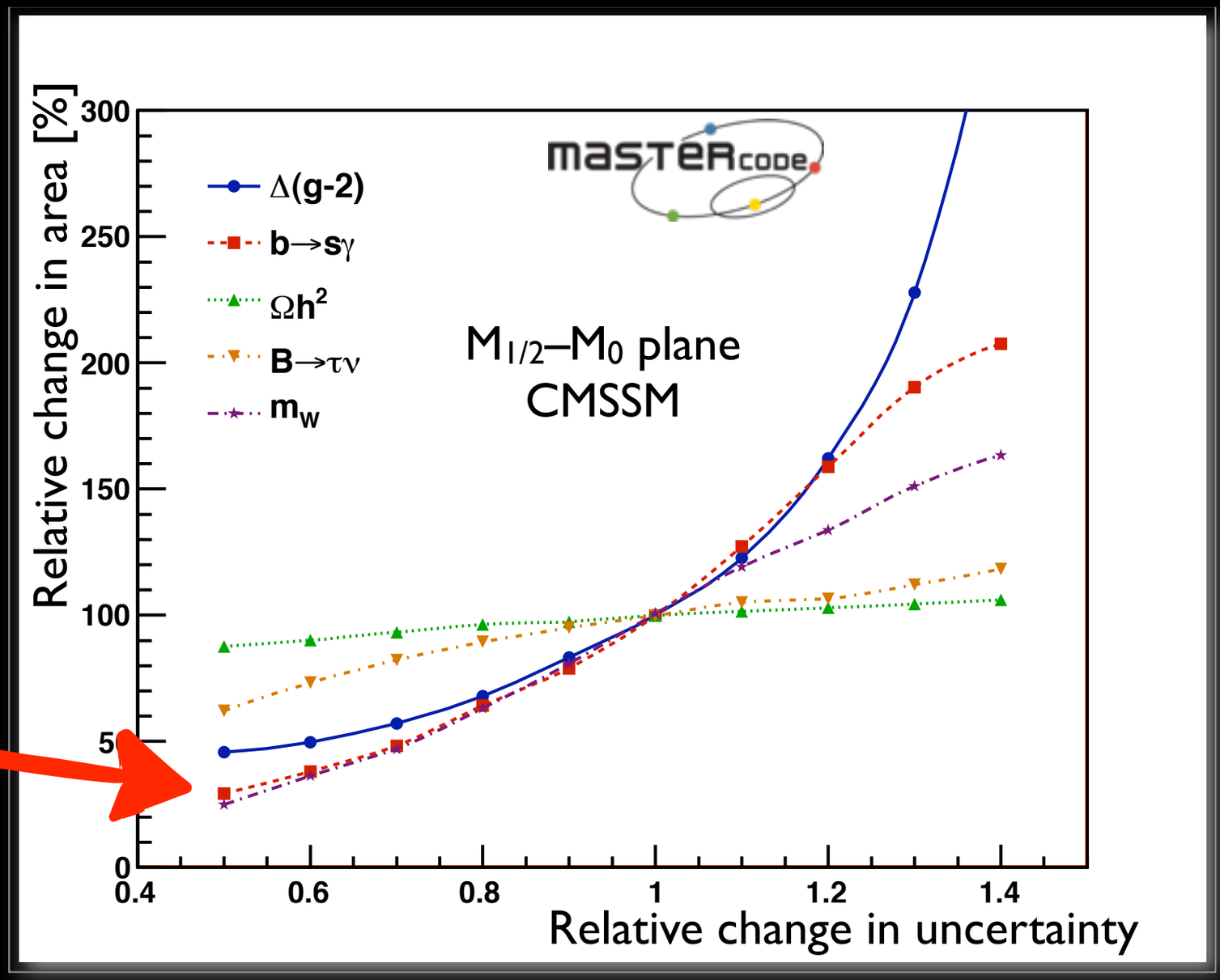
- Percent change of 95% C.L. contour area as a function of relative uncertainty

  - **in general, parameter space weakly constrained**
  - **g-2 still the strongest constraint**





Sensitivity to relic density

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- 95% CL contours with and without relic density (CMSSM)

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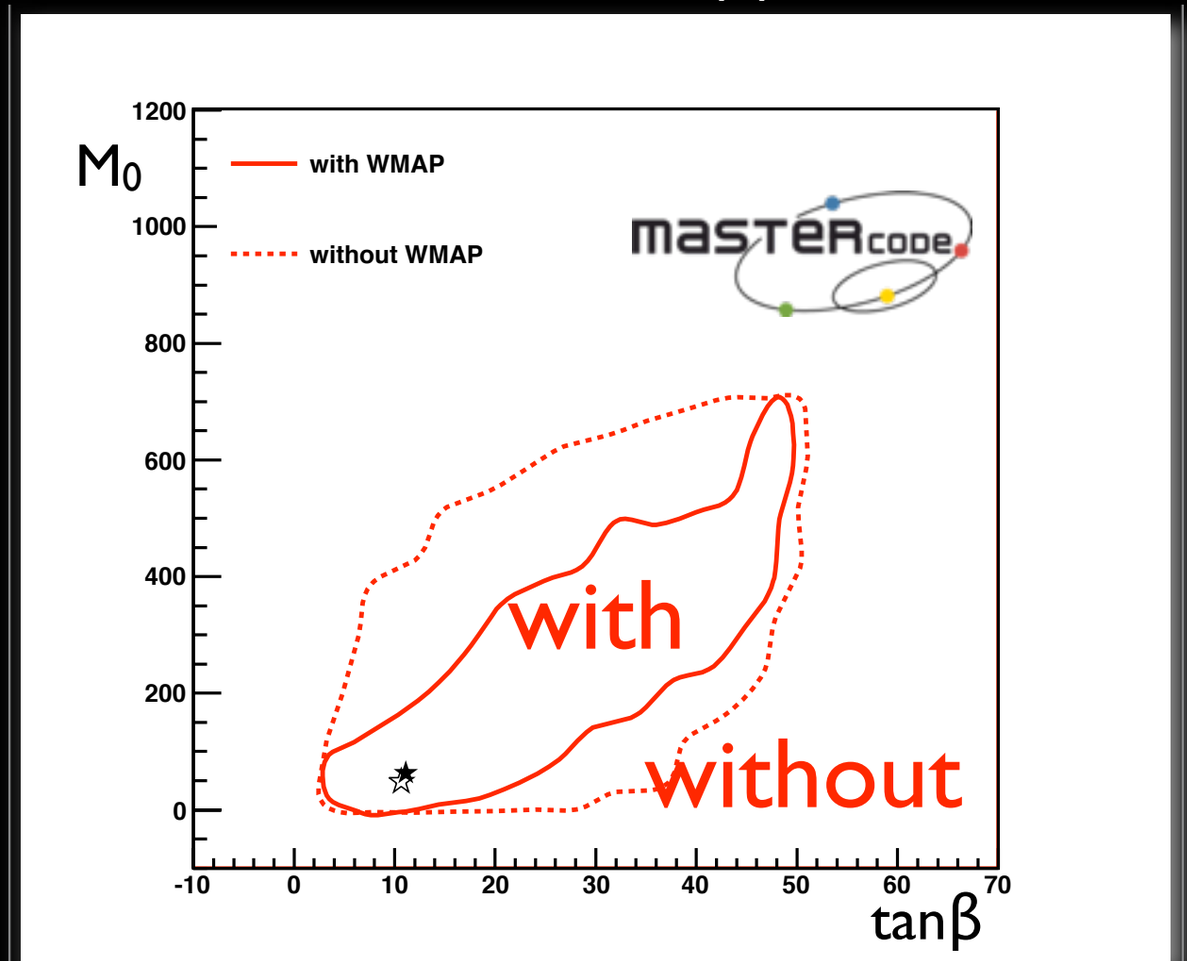
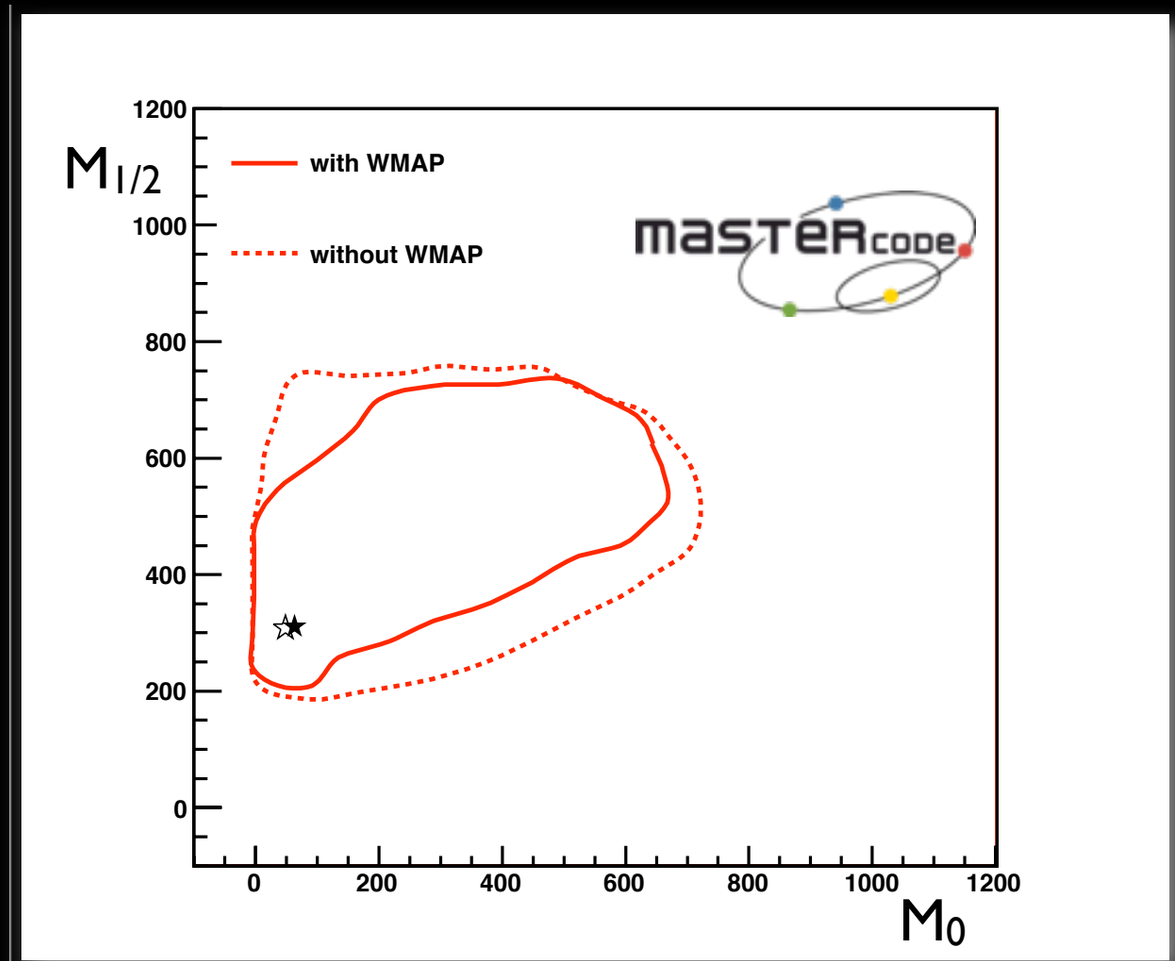


Variation of 95% CL contours
with and without WMAP constraint



Same, $M_{1/2}$ – M_0 plane

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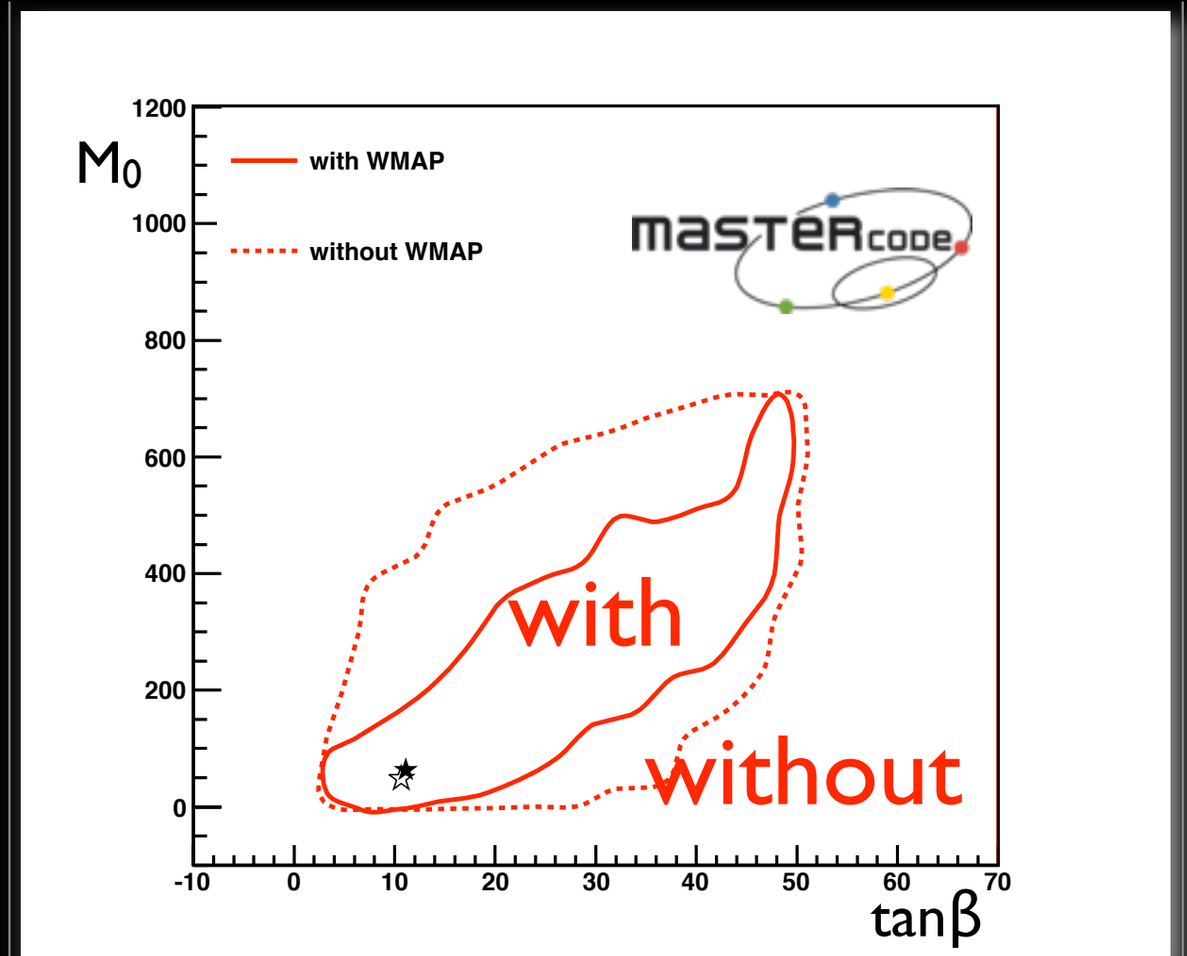

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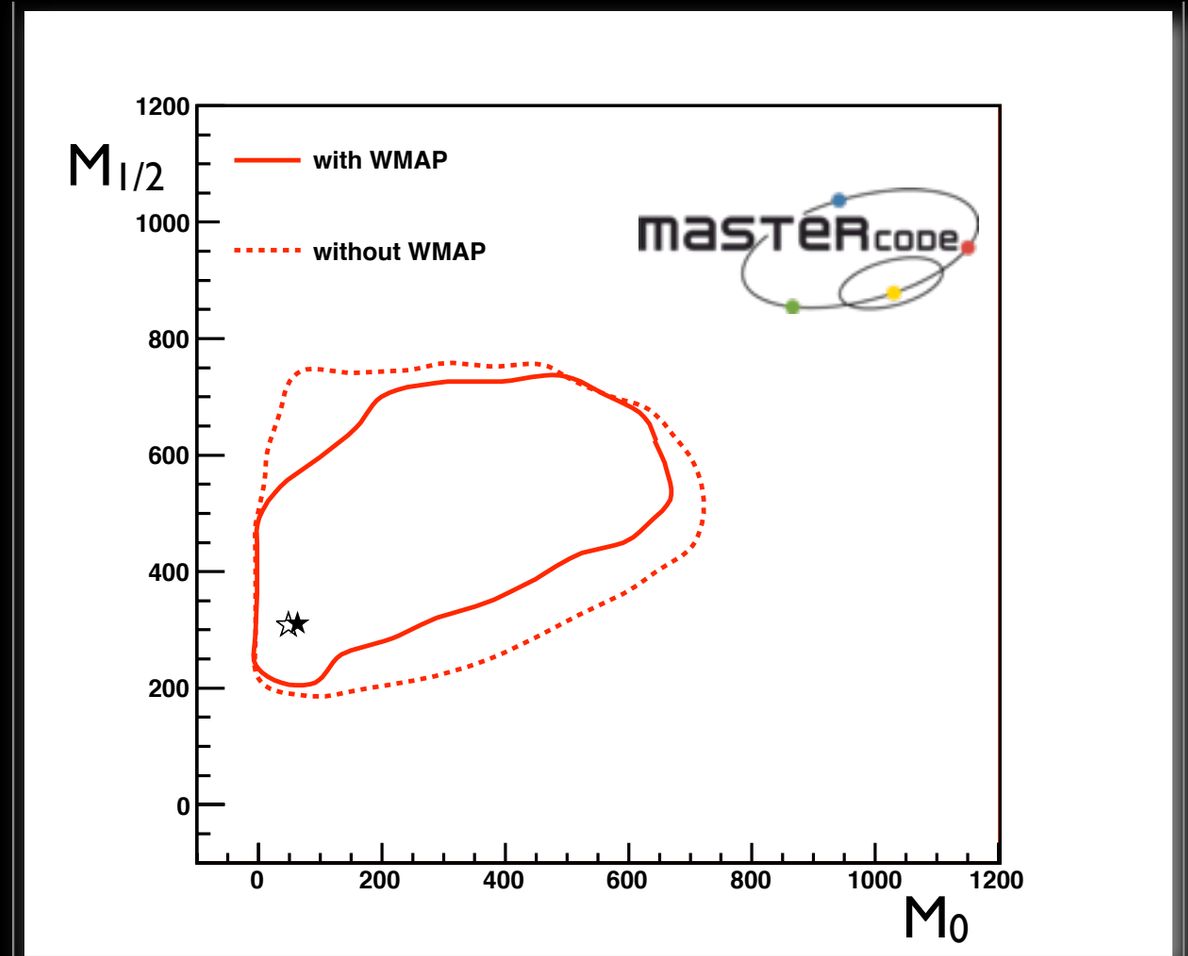

Same, $M_{1/2}$ – M_0 plane

➠ Present data already predicts relic density reasonably well?

Predictions for relic density

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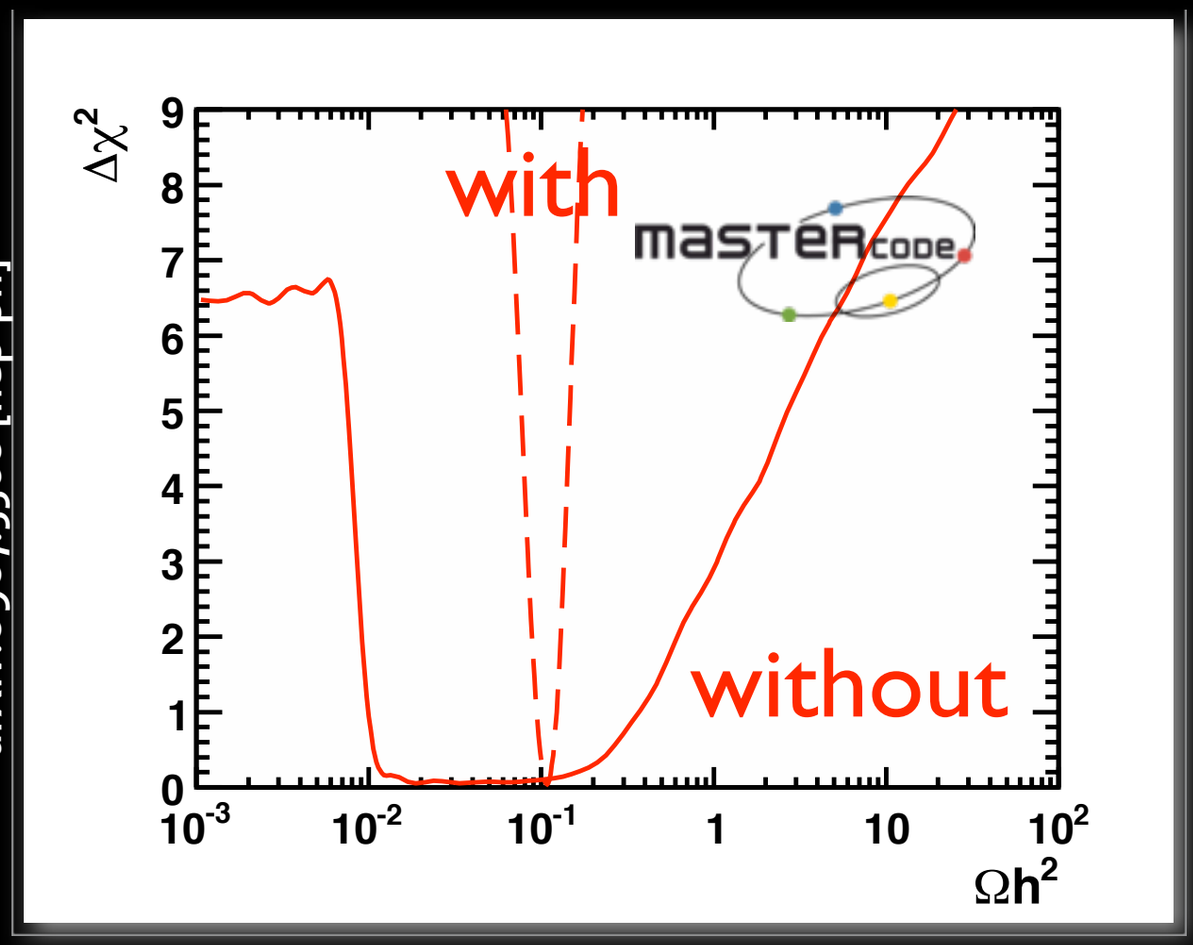
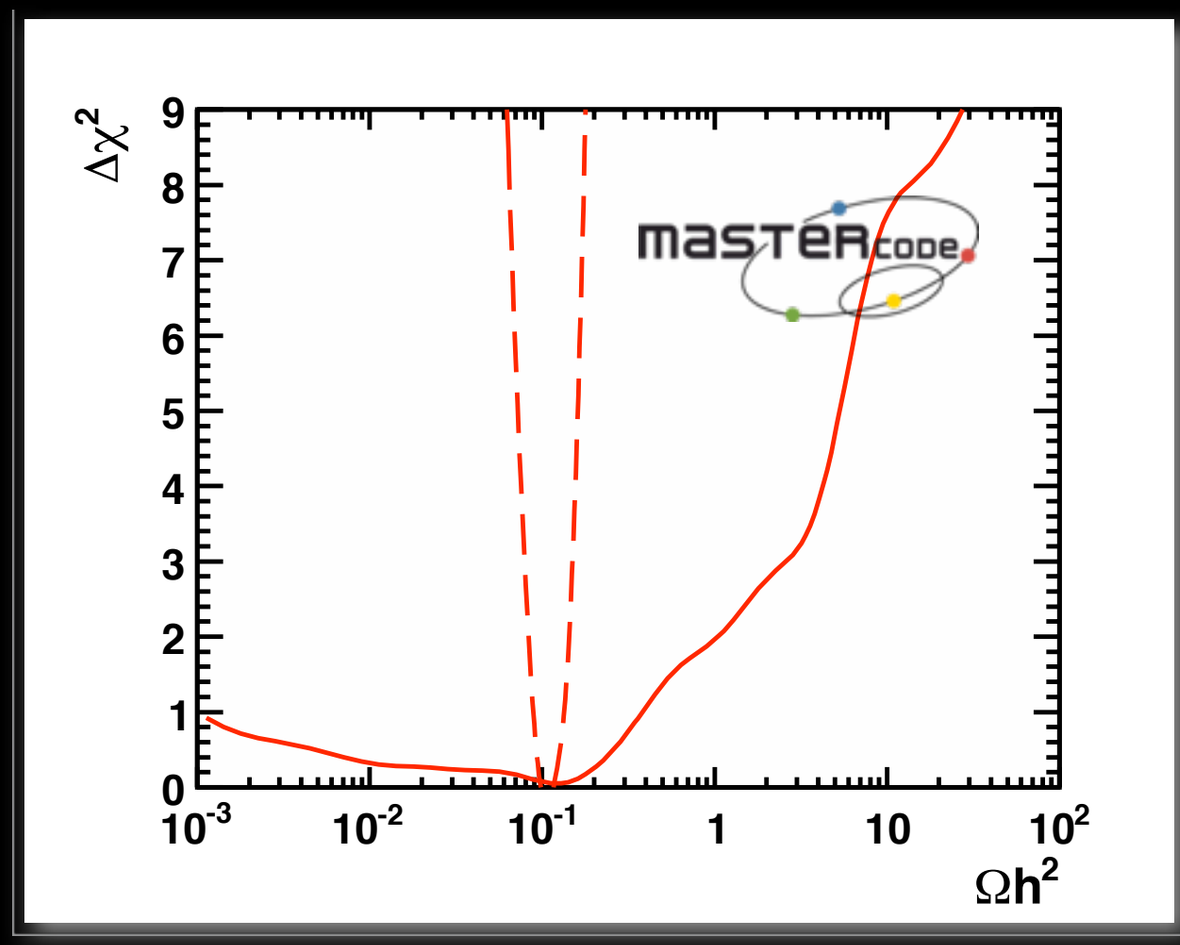
- Likelihood functions with and without relic density



CMSSM



NUHM1

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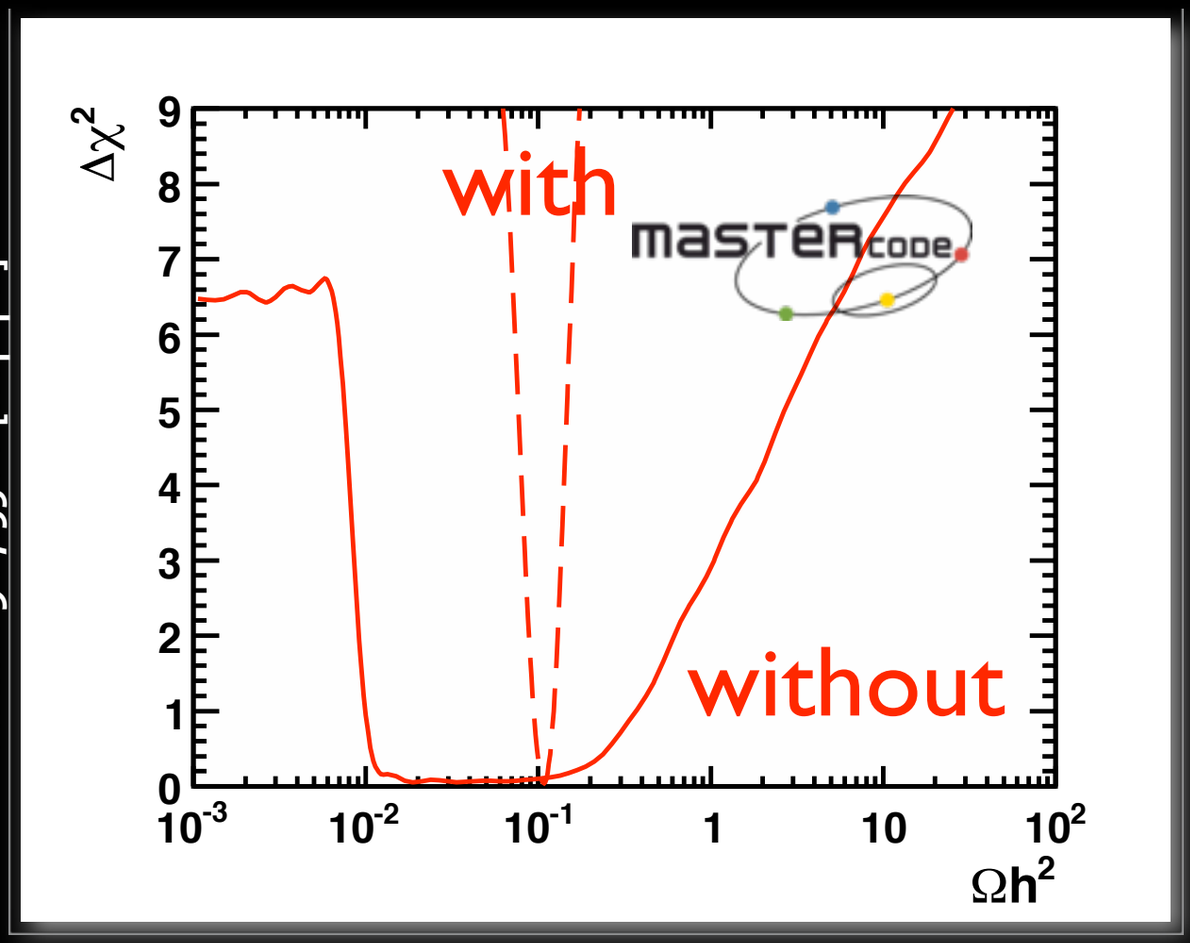

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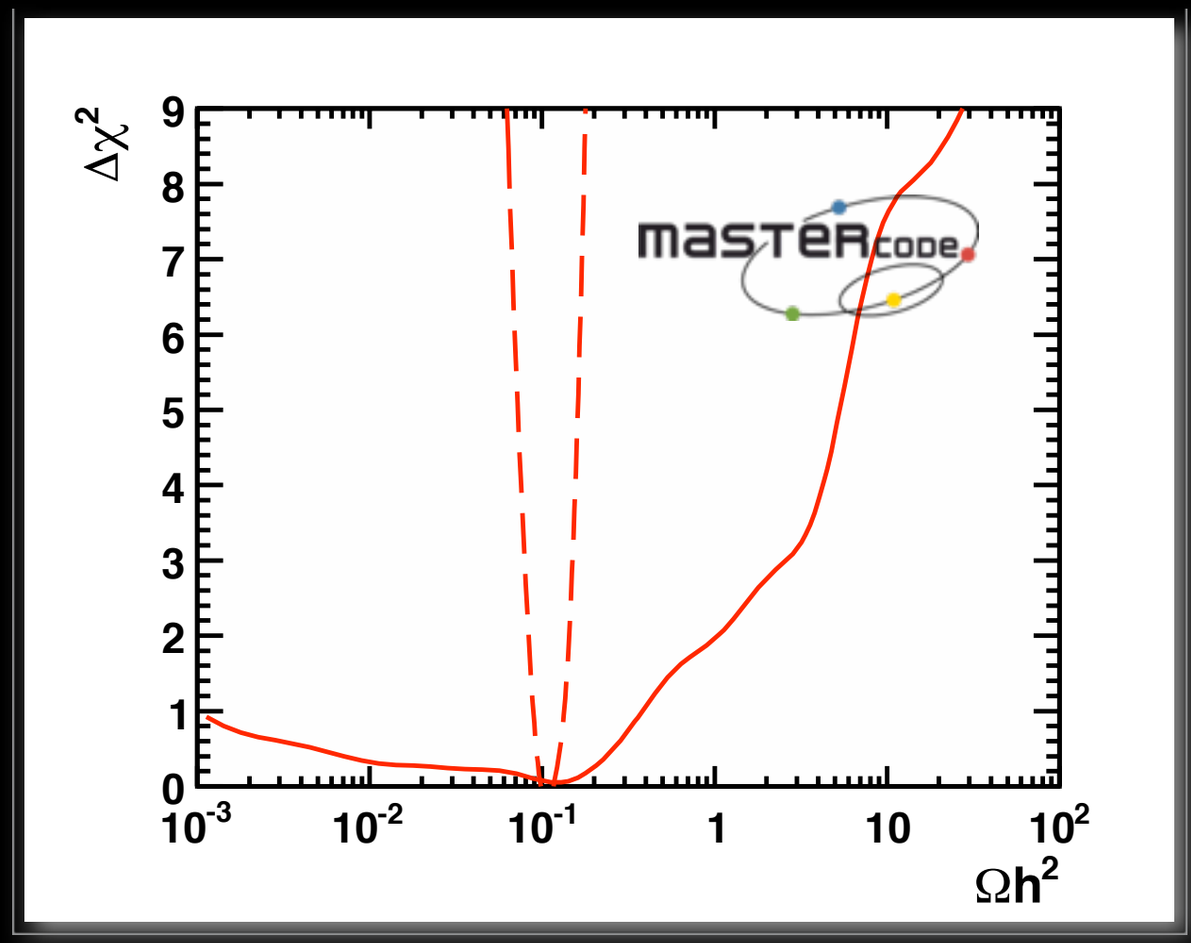

NUHM1

➠ Relic density "natural" in these models

Predictions for LSP mass

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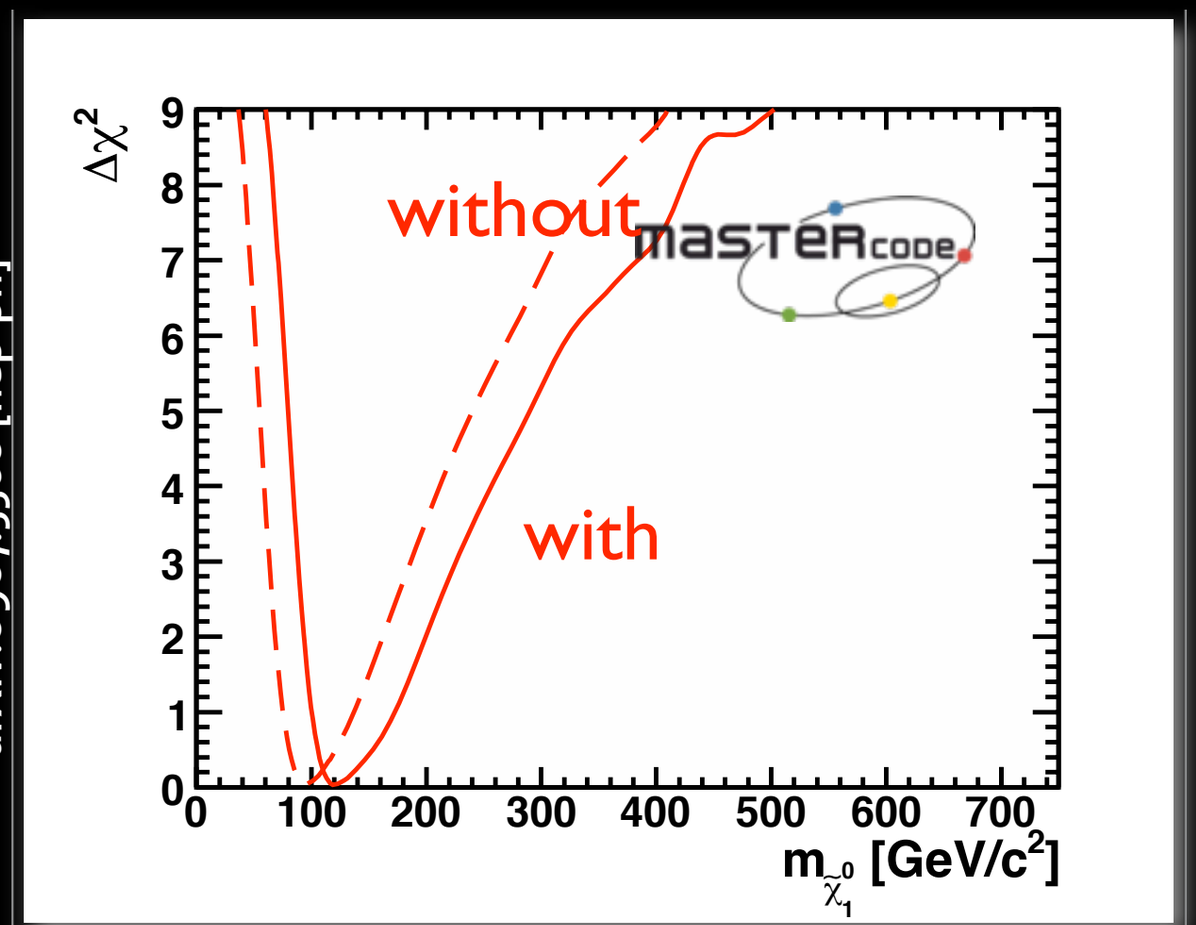
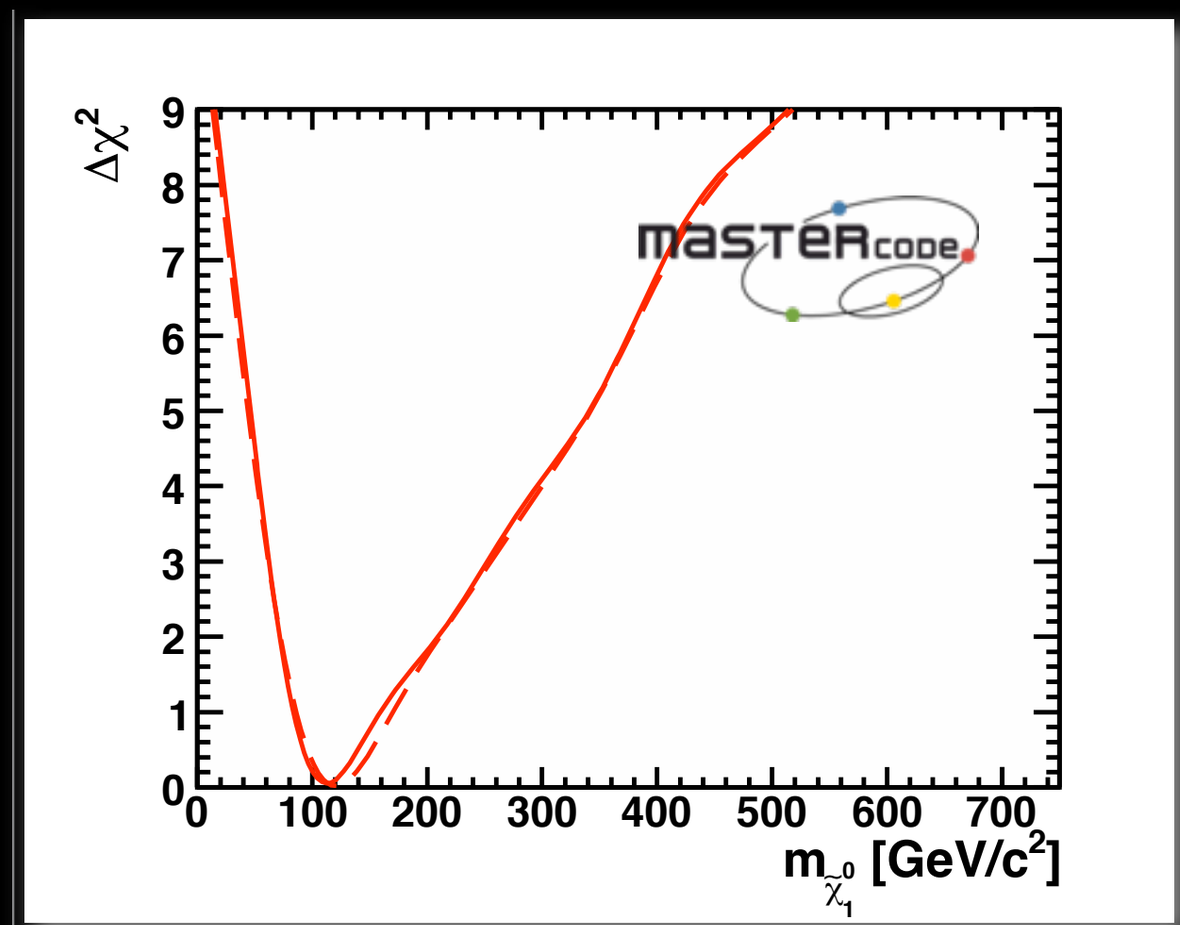
- Likelihood functions (with and without LEP Higgs limit)



LSP mass – CMSSM
(relic density constraint included)



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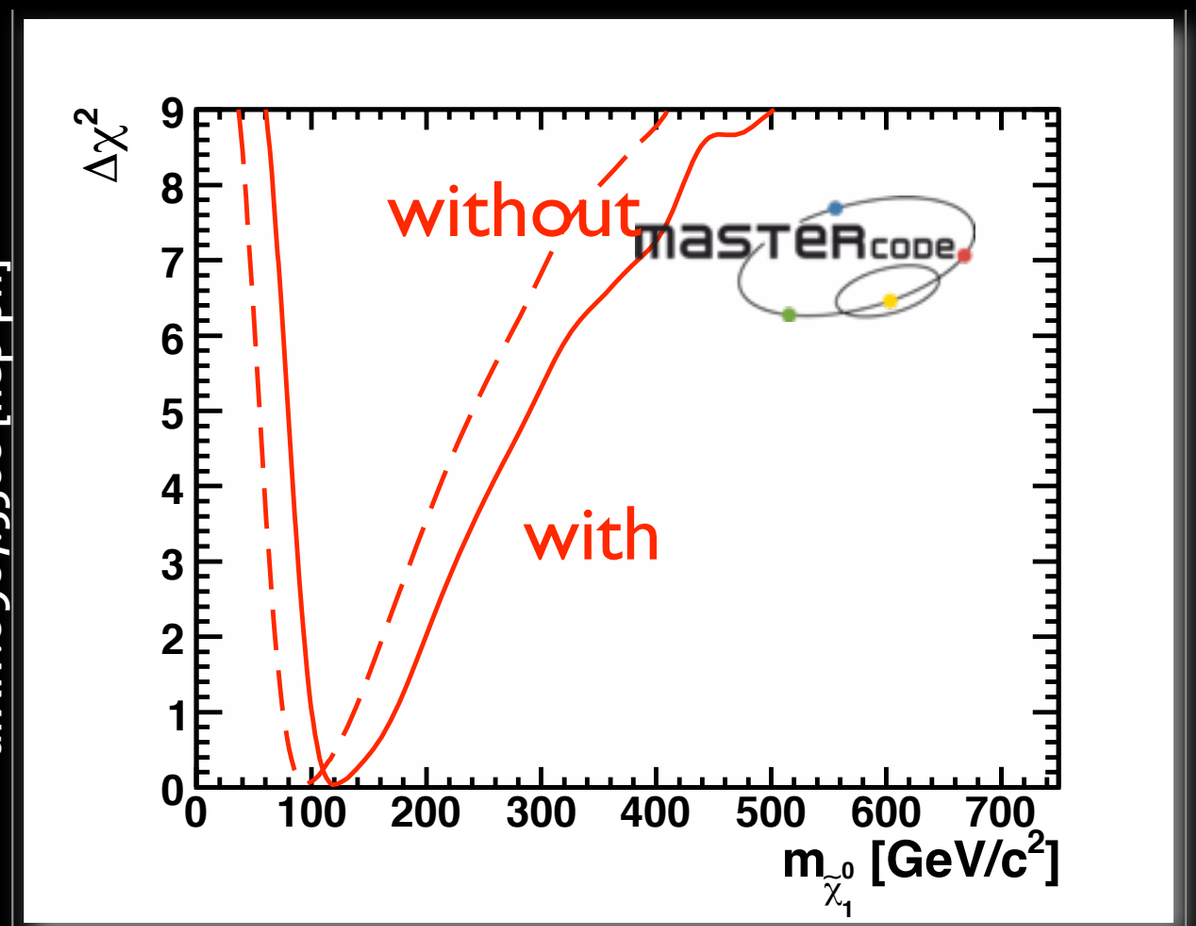

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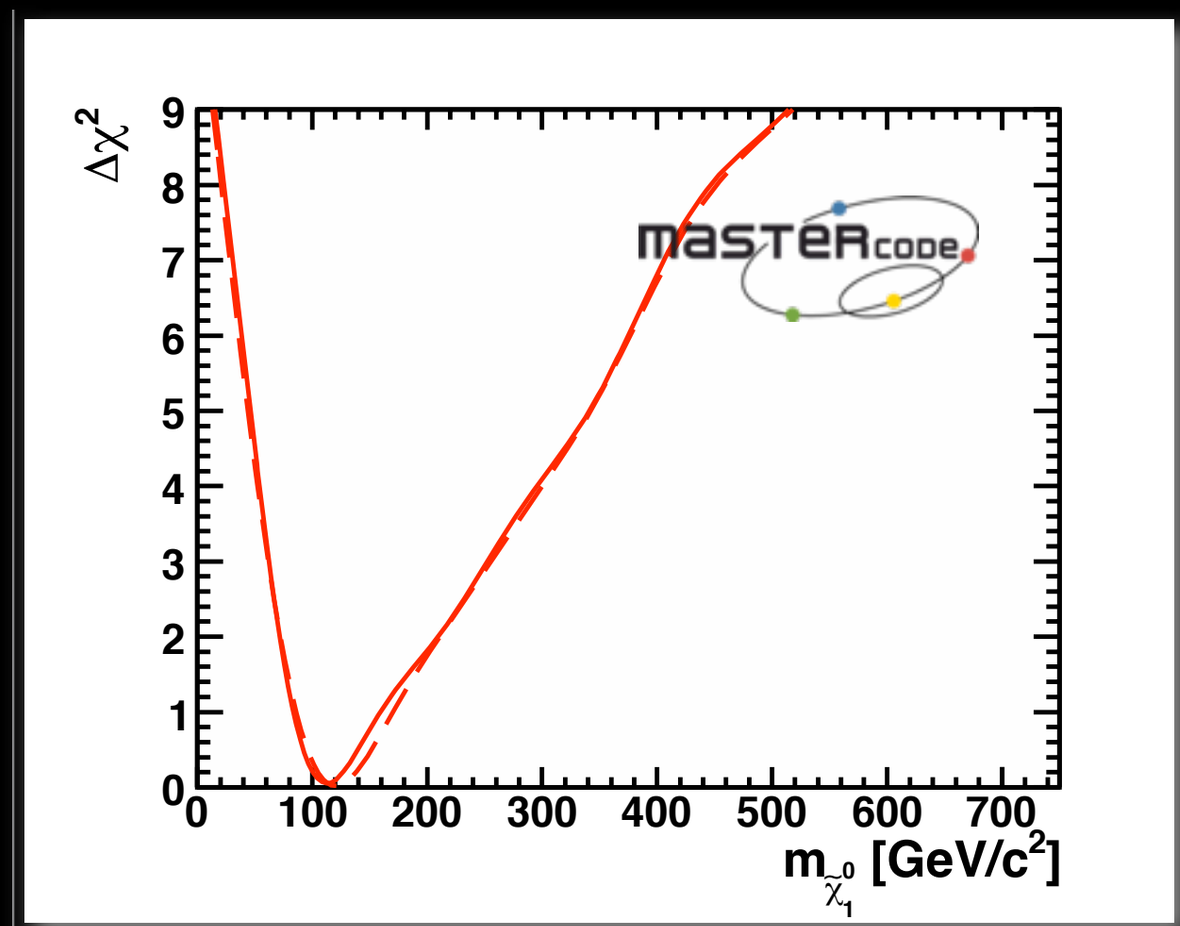


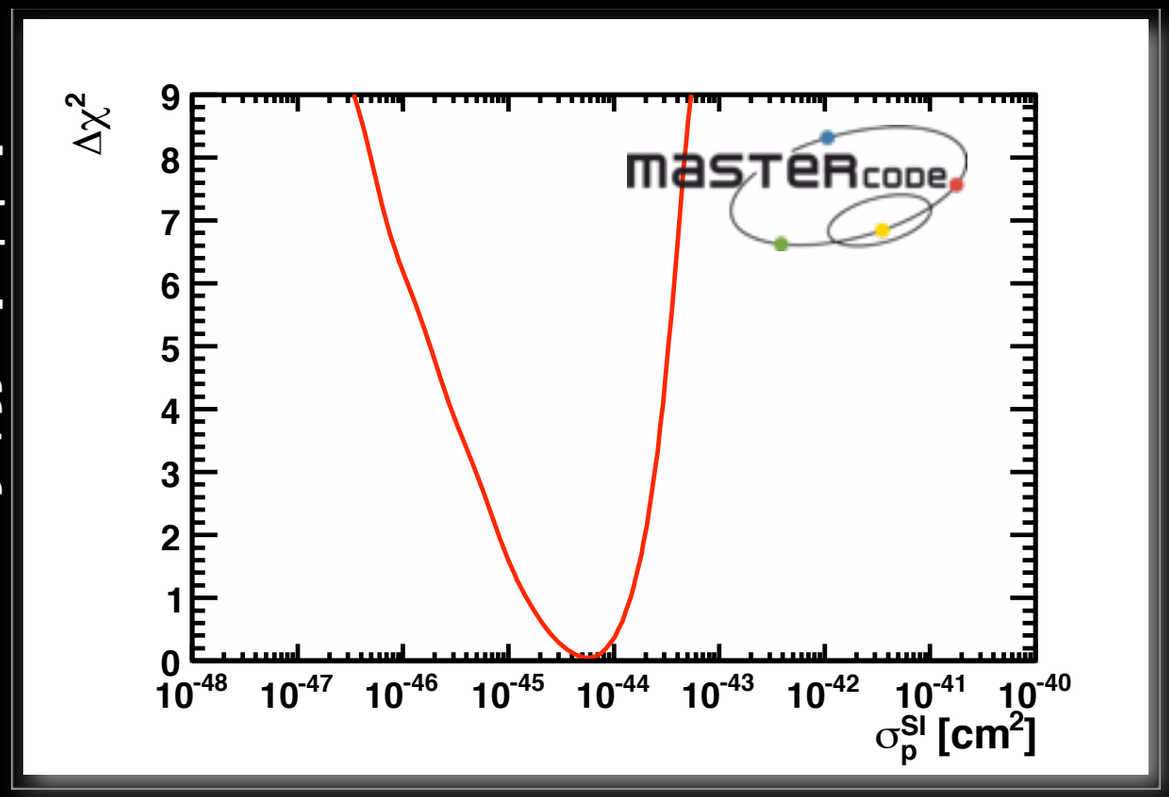
LSP mass – NUHM1

➠ Strong constraints on LSP mass

Predictions for cross-section

ETH Institute for Particle Physics

- Likelihood functions for spin-independent WIMP scattering cross-section



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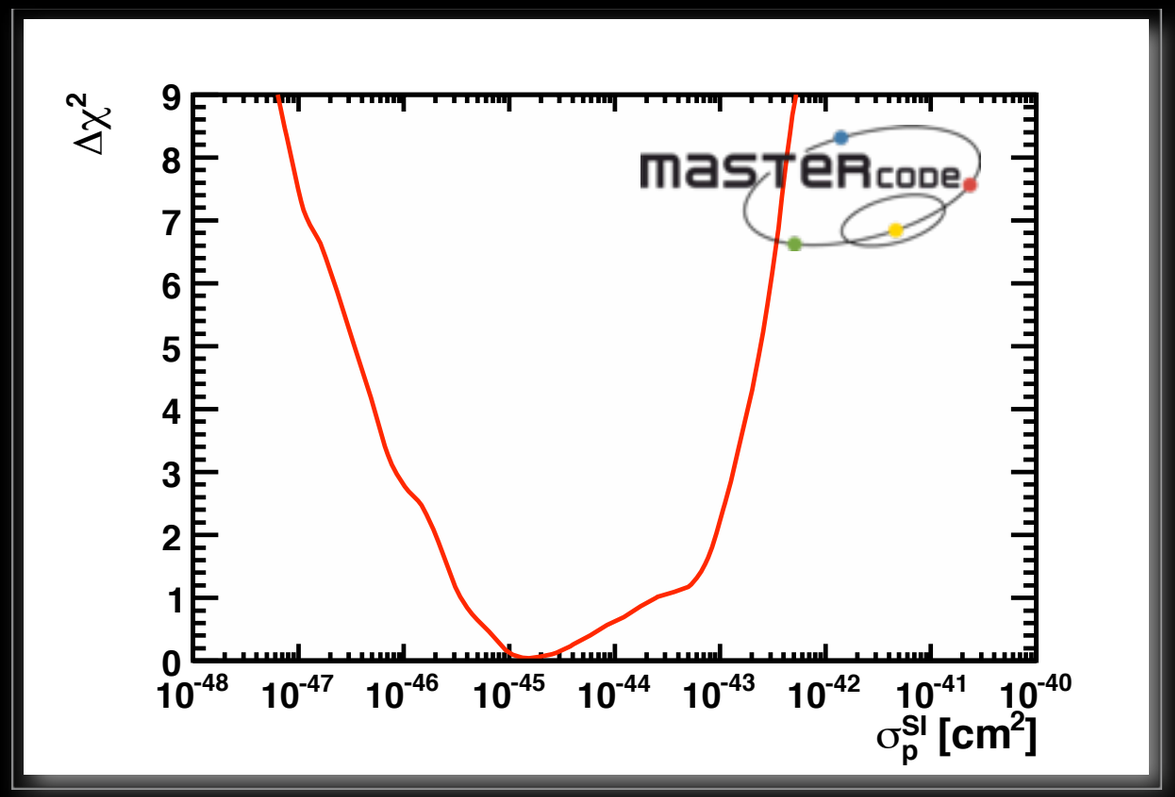

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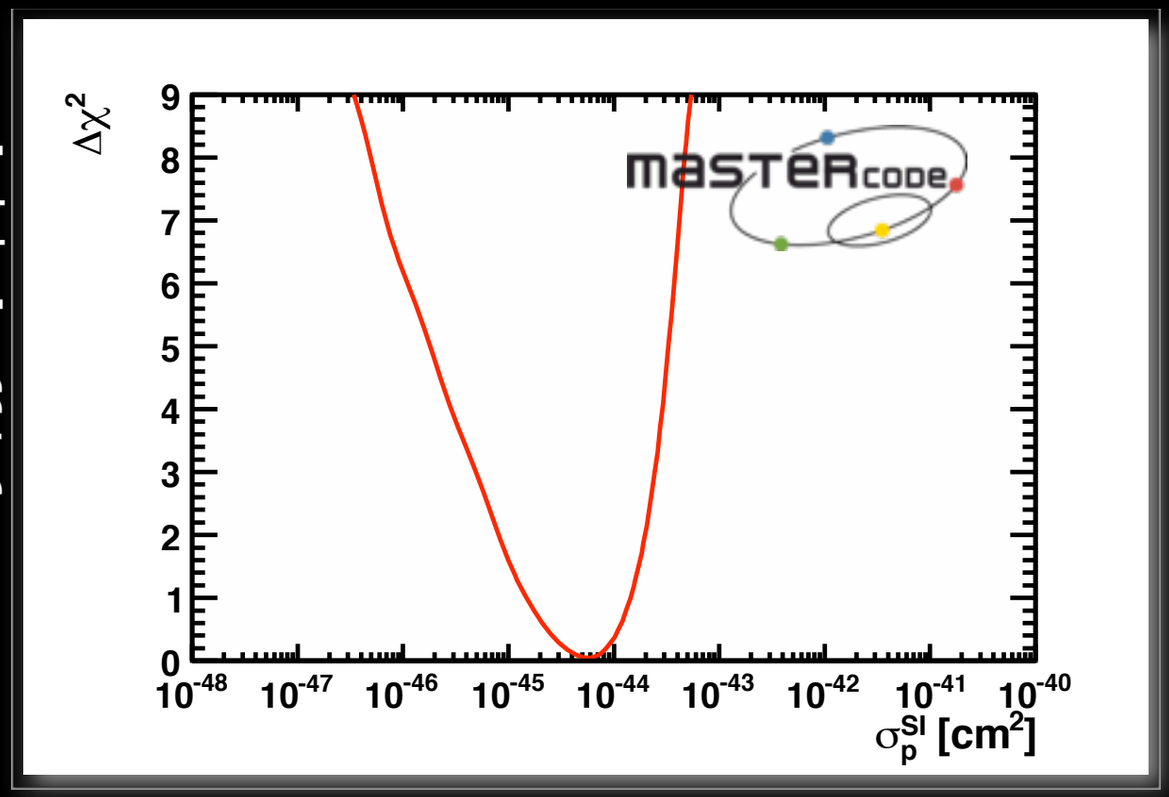

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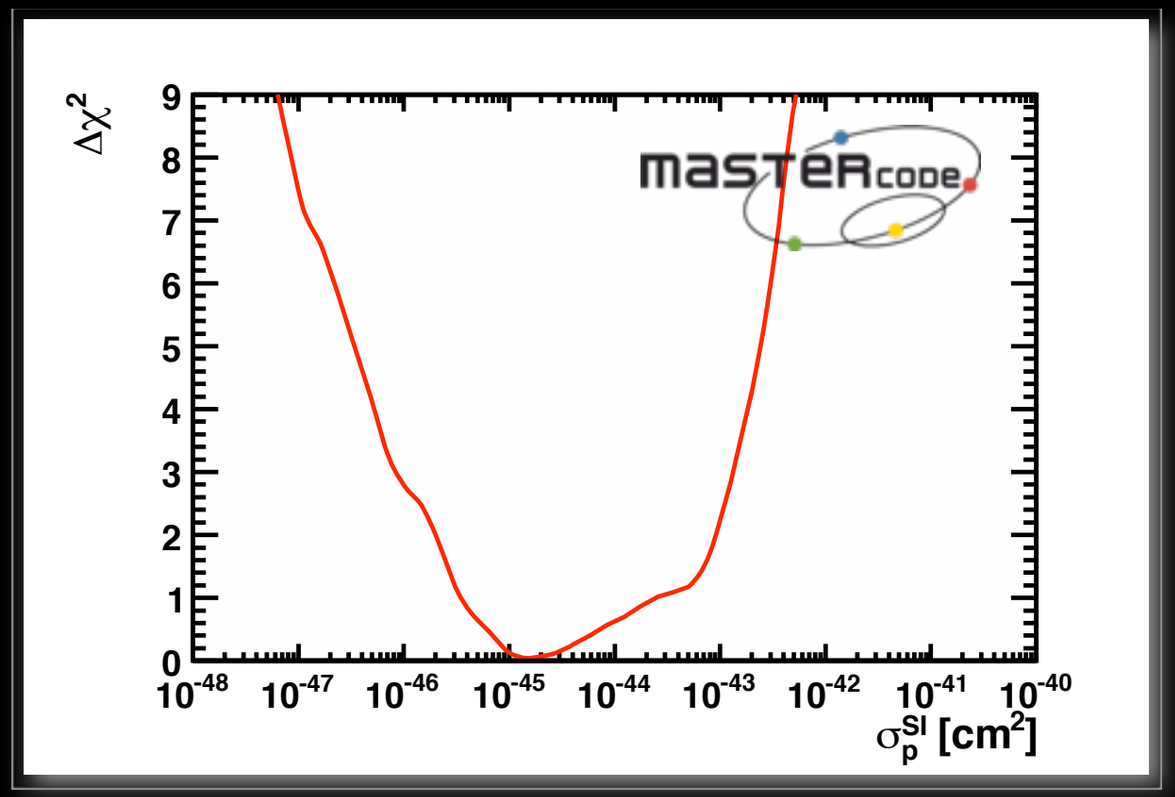

NUHM1

➠ Strong constraints on detection cross-section

Putting it all together...

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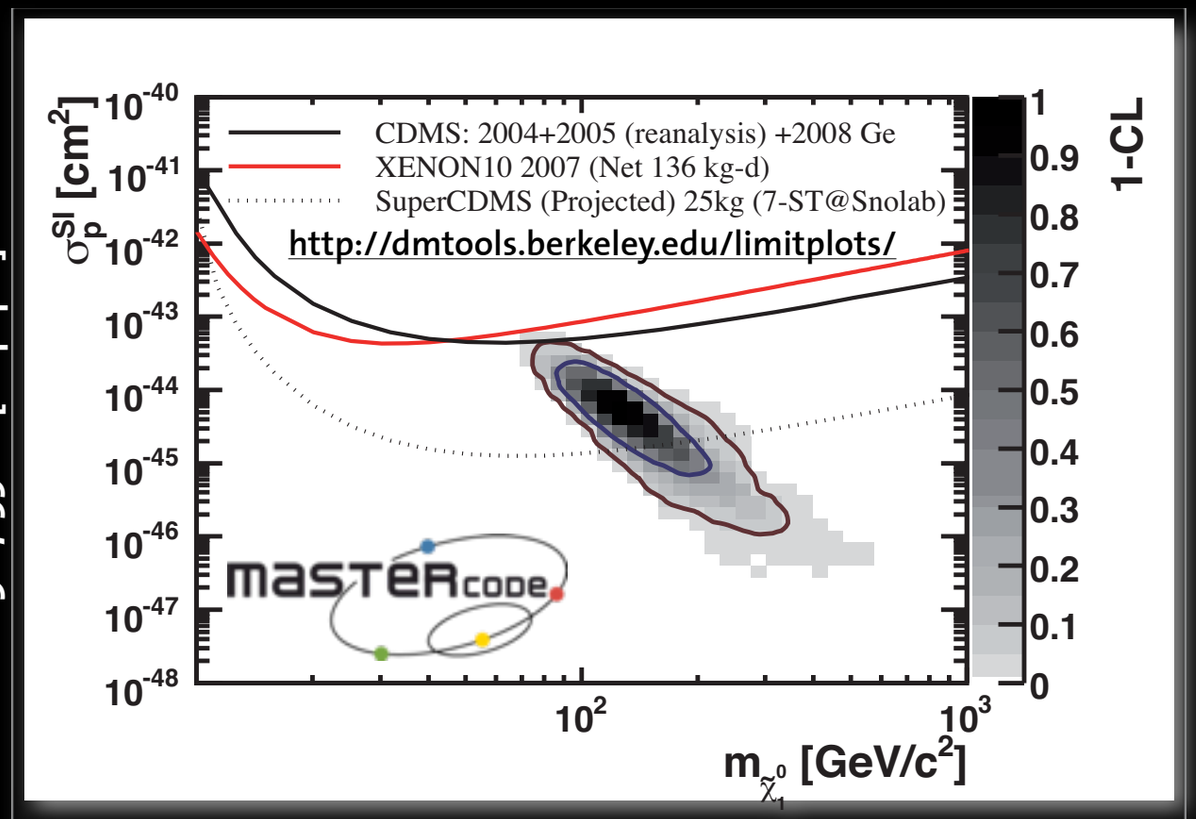
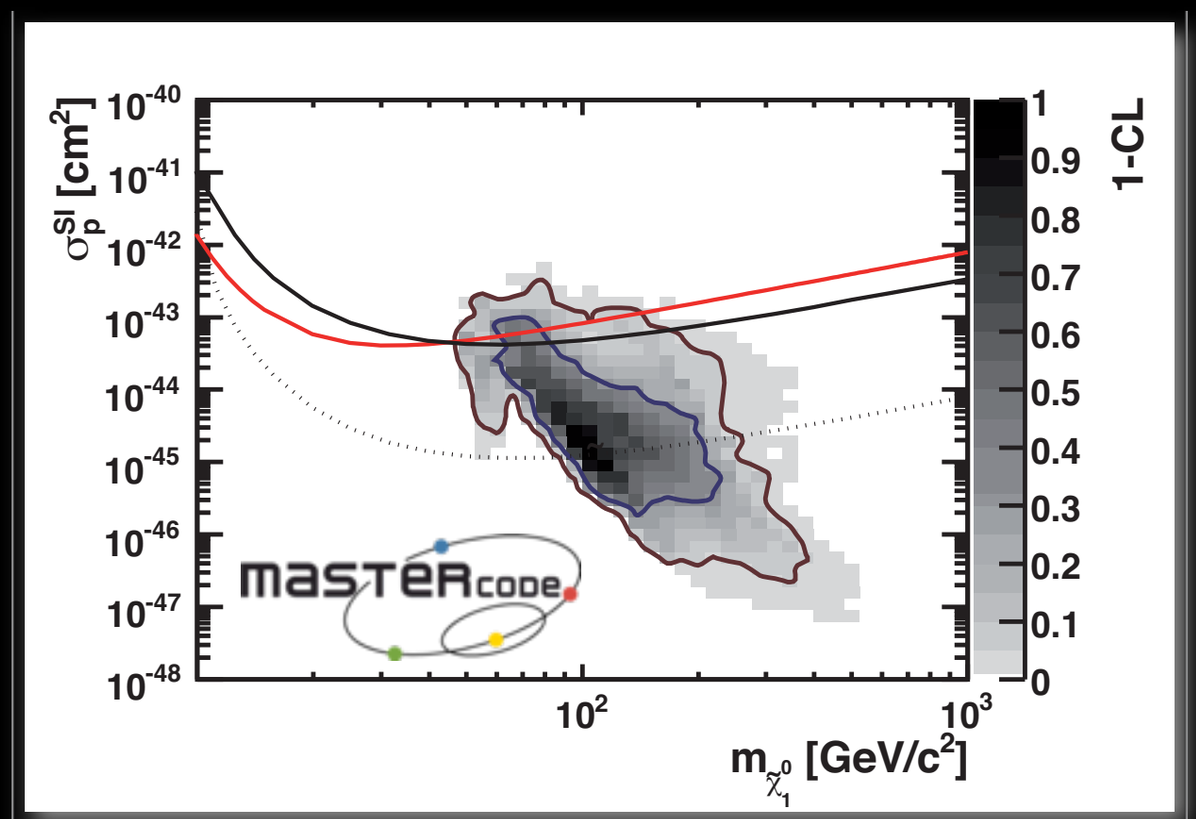
- "Expectation" for dark matter searches



Spin-independent cross-section vs. LSP mass
CMSSM



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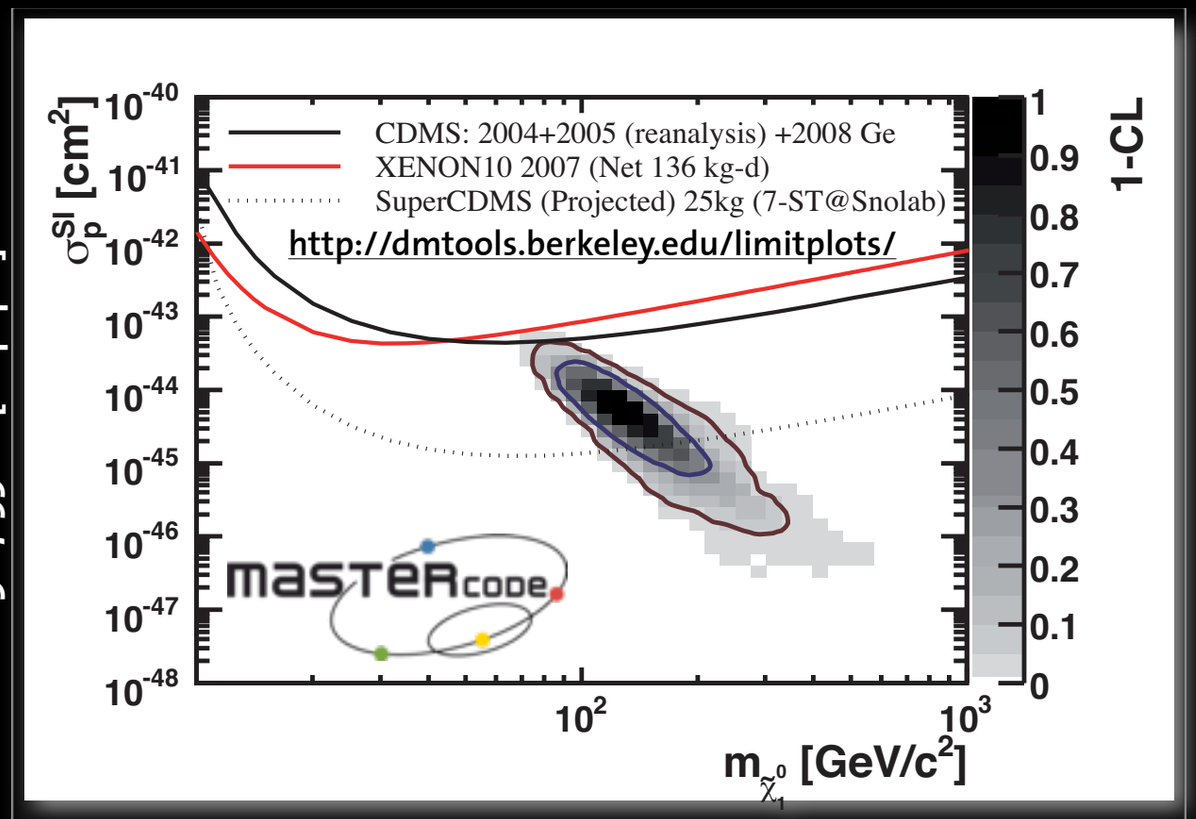

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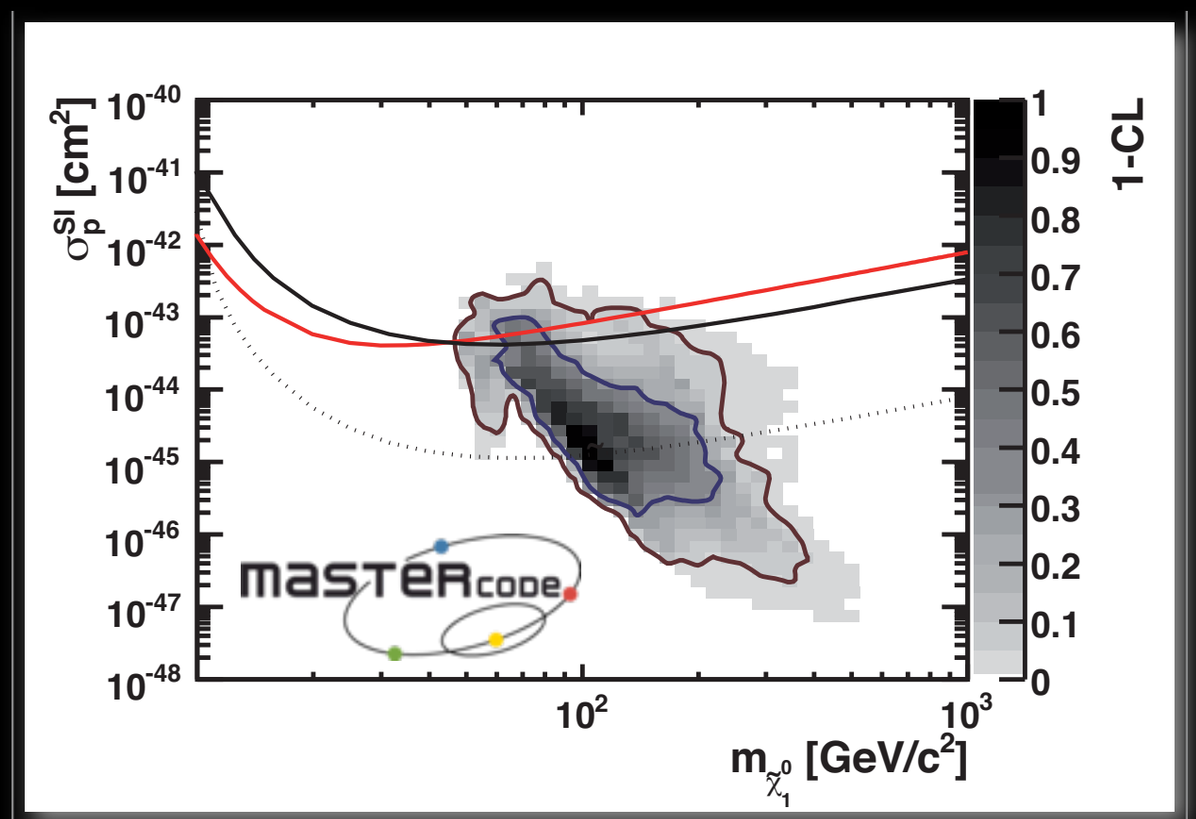

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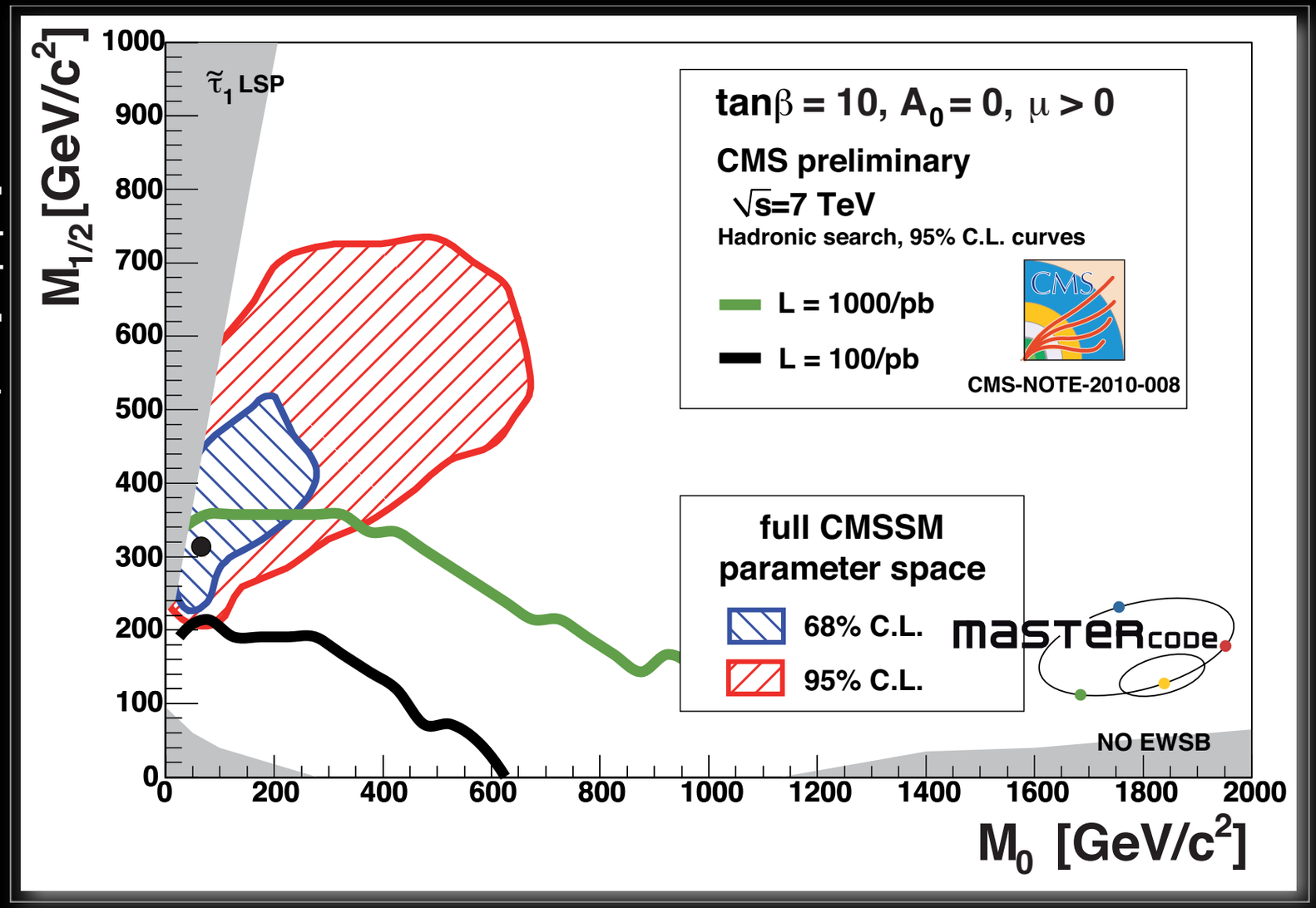
➠ We expect news very soon!

Global fits and the LHC

ETH Institute for Particle Physics

- Where we stand now
  - **SUSY searches at CMS**
  - **preferred CMSSM parameter space**



Global fits and the LHC

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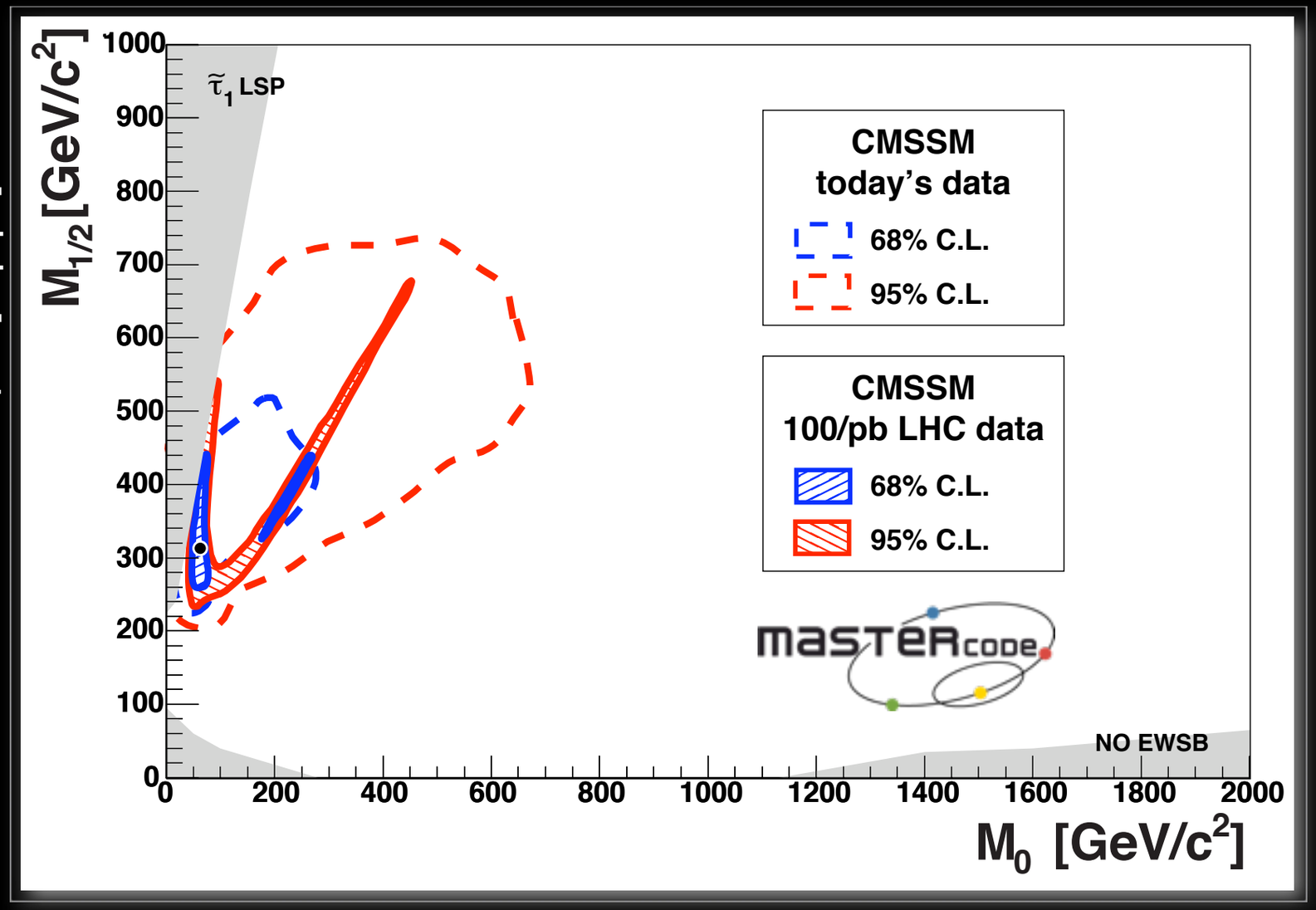
- Where we stand now
  - **SUSY searches at CMS**
  - **preferred CMSSM parameter space**
- Tomorrow?
  - **Dilepton edge measurement at CMS**
  - **1/fb integrated luminosity at 14 TeV**
- LHC-DM interplay!



Conclusions & Outlook

ETH Institute for Particle Physics

- Experimental constraints already exist
  - **powerful tool to set "expectation" in a given model**
  - **expectation within CMSSM and NUHM1 shown**
    - already strong constraints on LSP mass and scattering cross-section, in this context
    - DM searches will be able to discover LSP (or exclude these models) soon
  - **more interplay to come with the rise of the LHC**
    - first glance at interplay here: how about expectation at LHC from DM searches?...

- Future plans
  - **other models: mSUGRA, VCMSSM (more sensitive to Ωh^2)**
  - **more limits from DM related experiments in the fit**
  - **more measurements!**